

## DAFTAR ISI

|                                                                |              |
|----------------------------------------------------------------|--------------|
| <b>LEMBAR PENGESAHAN .....</b>                                 | <b>ii</b>    |
| <b>LEMBAR ORISINILITAS .....</b>                               | <b>iii</b>   |
| <b>ABSTRAK .....</b>                                           | <b>vi</b>    |
| <b><i>ABSTRACT</i> .....</b>                                   | <b>vii</b>   |
| <b>KATA PENGANTAR.....</b>                                     | <b>viii</b>  |
| <b>UCAPAN TERIMA KASIH.....</b>                                | <b>ix</b>    |
| <b>DAFTAR ISI.....</b>                                         | <b>x</b>     |
| <b>DAFTAR GAMBAR.....</b>                                      | <b>xiv</b>   |
| <b>DAFTAR TABEL .....</b>                                      | <b>xvii</b>  |
| <b>DAFTAR SINGKATAN.....</b>                                   | <b>xviii</b> |
| <b>BAB I PENDAHULUAN.....</b>                                  | <b>1</b>     |
| 1.1 Latar Belakang.....                                        | 1            |
| 1.2 Rumusan Masalah.....                                       | 3            |
| 1.3 Tujuan dan Manfaat.....                                    | 3            |
| 1.4 Batasan Masalah .....                                      | 4            |
| 1.5 Metode Penelitian .....                                    | 4            |
| 1.6 Jadwal Pelaksanaan .....                                   | 5            |
| <b>BAB II TINJAUAN DAN DASAR TEORI .....</b>                   | <b>7</b>     |
| 2.1 Kajian Pustaka .....                                       | 7            |
| 2.2 Dasar Teori .....                                          | 9            |
| 2.2.1 Indeks Pencemaran Udara (ISPU) .....                     | 9            |
| 2.2.2 <i>Internet Of Things</i> (IoT).....                     | 11           |
| 2.2.3 <i>Long Range</i> (LoRa).....                            | 13           |
| 2.2.4 <i>Long Range Wide Area Network</i> (LoRaWAN).....       | 14           |
| 2.2.5 <i>Message Queueing Telemetry Transport</i> (MQTT) ..... | 17           |
| 2.2.6 Parameter LoRaWAN .....                                  | 19           |
| 2.2.6.1 <i>Received Signal Strength Indicator</i> (RSSI).....  | 19           |
| 2.2.6.2 <i>Signal – to – Noise Ratio</i> (SNR) .....           | 20           |
| 2.2.6.3 <i>Spreading Factor</i> (SF) .....                     | 20           |
| 2.2.6.4 <i>Adaptive Data Rate</i> (ADR) .....                  | 21           |
| 2.2.6.5 <i>Bandwidth</i> .....                                 | 22           |

|                                                                |                                                            |           |
|----------------------------------------------------------------|------------------------------------------------------------|-----------|
| 2.2.6.6                                                        | <i>Code Rate</i> .....                                     | 23        |
| 2.2.6.7                                                        | <i>Packet Loss</i> .....                                   | 23        |
| 2.2.6.8                                                        | <i>Delay</i> .....                                         | 24        |
| 2.2.6.9                                                        | <i>Error</i> .....                                         | 24        |
| 2.2.7                                                          | <i>Network Server</i> .....                                | 24        |
| 2.2.8                                                          | <i>Application Server</i> .....                            | 25        |
| <b>BAB III METODOLOGI PENELITIAN DAN RANCANGAN SISTEM ....</b> |                                                            | <b>26</b> |
| 3.1                                                            | <i>Alat dan Bahan</i> .....                                | <b>26</b> |
| 3.1.1                                                          | <i>Hardware</i> .....                                      | 26        |
| 3.1.1.1                                                        | <i>Komputer</i> .....                                      | 26        |
| 3.1.1.2                                                        | <i>End Device</i> .....                                    | 26        |
| 3.1.1.3                                                        | <i>Gateway LoRa</i> .....                                  | 27        |
| 3.1.2                                                          | <i>Software</i> .....                                      | 28        |
| 3.1.2.1                                                        | <i>Chirpstack</i> .....                                    | 28        |
| 3.1.2.2                                                        | <i>OpenRemote</i> .....                                    | 29        |
| 3.2                                                            | <i>Alur Penelitian</i> .....                               | <b>30</b> |
| 3.3                                                            | <i>Arsitektur Sistem Pemantauan Pencemaran Udara</i> ..... | 31        |
| 3.4                                                            | <i>Perancangan End-Device</i> .....                        | 32        |
| 3.5                                                            | <i>Perancangan Gateway</i> .....                           | 35        |
| 3.6                                                            | <i>Perancangan Platform</i> .....                          | 40        |
| 3.6.1                                                          | <i>Perancangan Network Server</i> .....                    | 40        |
| 3.6.2                                                          | <i>Perancangan Application Server</i> .....                | 46        |
| <b>BAB IV ANALISIS HASIL.....</b>                              |                                                            | <b>53</b> |
| 4.1                                                            | <i>Skenario Pengujian</i> .....                            | 53        |
| 4.1.1                                                          | <i>Detail Pengujian Akurasi Sensor</i> .....               | 54        |
| 4.1.2                                                          | <i>Detail Pengujian Komunikasi Data</i> .....              | 55        |
| 4.1.3                                                          | <i>Detail Pengujian Cakupan Pemantauan</i> .....           | 55        |
| 4.1.4                                                          | <i>Detail Pengujian Penyimpanan Data</i> .....             | 56        |
| 4.1.5                                                          | <i>Detail Pengujian Tampilan Data</i> .....                | 57        |
| 4.2                                                            | <i>Hasil Pengujian Sistem</i> .....                        | 57        |
| 4.2.1                                                          | <i>Hasil Akurasi Sensor</i> .....                          | 58        |
| 4.2.1.1                                                        | <i>Hasil Akurasi Sensor Karbon Dioksida (CO)</i> .....     | 58        |

|                                         |                                                                      |            |
|-----------------------------------------|----------------------------------------------------------------------|------------|
| 4.2.1.2                                 | Hasil Akurasi Sensor Karbon Dioksida (CO <sub>2</sub> ).....         | 61         |
| 4.2.1.3                                 | Hasil Pengukuran Sampel CO pada Kondisi Normal .....                 | 63         |
| 4.2.1.4                                 | Hasil Pengukuran Sampel CO <sub>2</sub> pada Kondisi Normal .....    | 64         |
| 4.2.2                                   | Hasil Komunikasi Data .....                                          | 64         |
| 4.2.3                                   | Hasil Cakupan Pemantauan.....                                        | 66         |
| 4.2.3.1                                 | Hasil pengujian Cakupan Pemantauan <i>Uplink</i> .....               | 66         |
| 4.2.3.2                                 | Hasil Pengujian Cakupan Pemantauan <i>Downlink</i> .....             | 68         |
| 4.2.4                                   | Hasil Penyimpanan Data .....                                         | 69         |
| 4.2.5                                   | Hasil Tampilan Data .....                                            | 70         |
| 4.2.5.1                                 | Tampilan Data Gedung Rektorat .....                                  | 71         |
| 4.2.5.2                                 | Tampilan Data Gedung DSP .....                                       | 73         |
| 4.2.6                                   | Hasil Integrasi Sistem .....                                         | 74         |
| 4.3                                     | Analisis Sistem .....                                                | 80         |
| 4.3.1                                   | Analisis Hasil Akurasi Sensor.....                                   | 81         |
| 4.3.1.1                                 | Analisis Akurasi Sensor CO.....                                      | 81         |
| 4.3.1.2                                 | Analisis Akurasi Sensor CO <sub>2</sub> .....                        | 84         |
| 4.3.1.3                                 | Analisis Hasil Pengukuran Sampel CO pada Kondisi Normal .            | 88         |
| 4.3.1.4                                 | Analisis Hasil Pengukuran Sampel CO <sub>2</sub> pada Kondisi Normal | 88         |
| 4.3.2                                   | Analisis Hasil Komunikasi data .....                                 | 89         |
| 4.3.3                                   | Analisis Hasil Cakupan Pemantauan .....                              | 91         |
| 4.3.3.1                                 | Analisis Cakupan Pemantauan Data <i>Uplink</i> .....                 | 91         |
| 4.3.3.2                                 | Analisis Cakupan Pemantauan Data <i>Downlink</i> .....               | 94         |
| 4.3.4                                   | Analisis Hasil Penyimpanan Data .....                                | 98         |
| 4.3.5                                   | Analisis Hasil Tampilan Data .....                                   | 99         |
| 4.3.5.1                                 | Analisis Tampilan Data Gedung Rektorat .....                         | 99         |
| 4.3.5.2                                 | Analisis Tampilan Data Gedung DSP .....                              | 101        |
| 4.3.6                                   | Analisis Pengujian Integrasi.....                                    | 103        |
| <b>BAB V KESIMPULAN DAN SARAN .....</b> |                                                                      | <b>106</b> |
| 5.1                                     | Kesimpulan.....                                                      | 106        |
| 5.2                                     | Saran .....                                                          | 108        |
| <b>DAFTAR PUSTAKA .....</b>             |                                                                      | <b>109</b> |
| <b>LAMPIRAN.....</b>                    |                                                                      | <b>115</b> |

|                                               |     |
|-----------------------------------------------|-----|
| Lampiran 1. Hasil <i>Hardware</i> .....       | 115 |
| Lampiran 2. Kumpulan <i>Source Code</i> ..... | 118 |