

DAFTAR ISI

| | |
|---|------|
| HALAMAN JUDUL | ii |
| HALAMAN PERSETUJUAN | iii |
| PERNYATAAN | iv |
| KATA PENGANTAR | v |
| DAFTAR ISI | vii |
| DAFTAR GAMBAR | x |
| DAFTAR TABEL | xii |
| INTISARI | xiii |
| ABSTRACT | xiv |
| BAB I PENDAHULUAN | 1 |
| 1.1 Latar Belakang | 1 |
| 1.2 Rumusan Masalah | 2 |
| 1.3 Batasan Masalah | 2 |
| 1.4 Tujuan Penelitian | 3 |
| 1.5 Manfaat Penelitian | 3 |
| 1.6 Keaslian Penelitian | 3 |
| 1.7 Sistematika Penulisan | 3 |
| BAB II TINJAUAN PUSTAKA | 5 |
| BAB III LANDASAN TEORI | 11 |
| 3.1 Latar Belakang Jaringan LTE | 11 |
| 3.2 Arsitektur Jaringan LTE | 12 |
| 3.2.1 User Equipment (UE) | 12 |
| 3.2.2 eNodeB | 13 |
| 3.2.3 Mobility Management Entity (MME) | 14 |
| 3.2.4 Serving Gateway (S-GW) | 14 |
| 3.2.5 Packet Data Network Gateway (P-GW) | 15 |
| 3.3 Teknik Akses Jaringan LTE | 16 |
| 3.3.1 Orthogonal Frequency Division Multiplexing | 16 |
| 3.3.2 Orthogonal Frequency Division Multiple Access | 17 |
| 3.3.3 Single Carrier Frequency Division Multiple Access | 19 |
| 3.4 Mode Akses Radio | 19 |
| 3.4.1 Frequency Division Duplex | 20 |
| 3.4.2 Time Division Duplex | 20 |
| 3.5 Video Streaming | 21 |
| 3.5.1 Kualitas Video Streaming | 22 |
| 3.5.2 Video Codec H.264 | 24 |
| 3.5.3 Parameter Video Streaming | 25 |
| 3.5.3.1 Delay | 25 |
| 3.5.3.2 Packet Loss | 27 |
| 3.5.3.3 Throughput | 27 |
| 3.6 Handover | 28 |
| 3.6.1 Soft Handover | 30 |
| 3.6.2 Hard Handover | 31 |

| | | |
|---------------|--|-----------|
| 3.6.3 | X2 Handover | 31 |
| 3.7 | Network Simulator 3 | 33 |
| 3.7.1 | Modul Jaringan LTE Pada Network Simulator 3 | 35 |
| BAB IV | RANCANGAN PENELITIAN | 37 |
| 4.1 | Studi Pustaka..... | 38 |
| 4.2 | Analisis Kebutuhan Sistem..... | 38 |
| 4.2.1 | Kebutuhan Perangkat Keras | 38 |
| 4.2.2 | Kebutuhan Perangkat Lunak | 39 |
| 4.3 | Perancangan dan Implementasi Model Simulasi... .. | 39 |
| 4.3.1 | Model Simulasi Jaringan LTE..... | 39 |
| 4.3.2 | IP Address Node..... | 40 |
| 4.3.3 | Perancangan Video Streaming | 42 |
| 4.4 | Mekanisme Handover..... | 43 |
| 4.5 | Skenario Pengujian..... | 46 |
| 4.6 | Pengambilan Data..... | 47 |
| BAB V | IMPLEMENTASI DAN PENGUJIAN SISTEM..... | 48 |
| 5.1 | Perangkat Simulasi | 48 |
| 5.2 | Implementasi Perancangan Model Simulasi Jaringan LTE | 48 |
| 5.2.1 | Implementasi Remote Host | 48 |
| 5.2.2 | Implementasi SGW/PGW Node..... | 49 |
| 5.2.3 | Implementasi Internet | 49 |
| 5.2.4 | Implementasi IP Address Remote Host dan SGW/PGW..... | 50 |
| 5.2.5 | Implementasi IP Address User Equipment | 50 |
| 5.2.6 | Implementasi User Equipment dan eNodeB | 51 |
| 5.2.7 | Implementasi Jaringan LTE pada User Equipment dan eNodeB .. | 52 |
| 5.2.8 | Implementasi IP Address dan Internet pada User Equipment..... | 52 |
| 5.2.9 | Implementasi User Equipment pada eNodeB | 53 |
| 5.2.10 | Implementasi IP Address pada X2 Interface dan S2 Interface ... | 53 |
| 5.2.11 | Implementasi Video Streaming | 54 |
| 5.2.12 | Implementasi X2 Handover..... | 55 |
| 5.2.13 | Implementasi Untuk Menjalankan aplikasi video streaming pada User Equipment dan Remote Host | 57 |
| 5.2.14 | Implementasi NetAnim | 58 |
| 5.2.15 | Implementasi Flow Monitor..... | 59 |
| 5.2.16 | Implementasi Grafik Delay, Packet Loss, Througput..... | 60 |
| 5.3 | Implementasi Skenario Pengujian | 62 |
| 5.3.1 | Pengujian simulasi tanpa visualisasi..... | 63 |
| 5.3.2 | Pengujian simulasi dengan Python | 64 |
| 5.3.3 | Pengujian simulasi dengan NetAnim..... | 65 |
| 5.4 | Implementasi Pengambilan Data..... | 67 |
| 5.4.1 | Perintah Menampilkan Grafik Delay | 68 |
| 5.4.2 | Perintah Menampilkan Grafik Packet Loss..... | 68 |
| 5.4.3 | Perintah Menampilkan Grafik Throughput | 69 |
| BAB VI | HASIL PENELITIAN DAN PEMBAHASAN | 71 |
| 6.1 | Nilai Rata-rata Delay untuk Kecepatan 40 Km/Jam, 70 Km/Jam dan 100 Km/Jam..... | 71 |

| | |
|--|----|
| 6.2 Nilai Rata-rata Packet Loss untuk Kecepatan 40 Km/Jam, 70 Km/Jam dan 100 Km/Jam | 72 |
| 6.3 Nilai Rata-rata Throughput untuk Kecepatan 40 Km/Jam, 70 Km/Jam dan 100 Km/Jam | 73 |
| BAB VII PENUTUP..... | 75 |
| 7.1 Kesimpulan | 75 |
| 7.2 Saran | 76 |
| DAFTAR PUSTAKA | 77 |

DAFTAR GAMBAR

| | | |
|-------------|---|----|
| Gambar 3.1 | Evolusi Teknologi Telekomunikasi Nirkabel | 11 |
| Gambar 3.2 | Arsitektur Dasar Jaringan LTE | 12 |
| Gambar 3.3 | Fungsi Utama eNodeB | 13 |
| Gambar 3.4 | Fungsi Utama Mobility Management Entity | 14 |
| Gambar 3.5 | Fungsi Utama Serving Gateway | 15 |
| Gambar 3.6 | Fungsi Utama Packet Data Network Gateway | 15 |
| Gambar 3.7 | Arah Transmisi Pada Jaringan LTE | 16 |
| Gambar 3.8 | Teknik Modulasi Multicarrier..... | 17 |
| Gambar 3.9 | Perbedaan OFDM dan OFDMA | 18 |
| Gambar 3.10 | Struktur Simbol Subcarrier OFDMA | 18 |
| Gambar 3.11 | Skema Mode Frequency Division Duplex | 20 |
| Gambar 3.12 | Struktur Uplink dan Downlink FDD | 20 |
| Gambar 3.13 | Skema Mode Time Division Duplex..... | 21 |
| Gambar 3.14 | Struktur Uplink dan Downlink TDD..... | 21 |
| Gambar 3.15 | Proses Handover | 28 |
| Gambar 3.16 | Proses Tahapan Handover | 30 |
| Gambar 3.17 | Soft Handover | 30 |
| Gambar 3.18 | Hard Handover..... | 31 |
| Gambar 3.19 | Prosedur X2 Handover | 33 |
| Gambar 3.20 | Modul Jaringan Pada Network Simulator 3..... | 35 |
| Gambar 3.21 | Modul Jaringan LTE Pada Network Simulator 3..... | 35 |
| Gambar 3.22 | Visualisasi Network Simulator 3 | 36 |
| Gambar 4.1 | Diagram Alur Tahapan Penelitian..... | 37 |
| Gambar 4.2 | Model Simulasi Jaringan LTE | 39 |
| Gambar 4.3 | Model Simulasi Penelitian..... | 40 |
| Gambar 4.4 | Konfigurasi IP Address | 42 |
| Gambar 4.5 | User Equipment Melakukan Handover | 44 |
| Gambar 4.6 | Flowchart Tahapan Proses Handover..... | 45 |
| Gambar 5.1 | Kode Program Implementasi Remote Host | 49 |
| Gambar 5.2 | Kode Program Implementasi SGW/PGW Node..... | 49 |
| Gambar 5.3 | Kode Program Implementasi Internet | 50 |
| Gambar 5.4 | Kode Program Implementasi IP Address Remote Host dan GW/PGW..... | 50 |
| Gambar 5.5 | Kode Program Implementasi IP Address User Equipment | 51 |
| Gambar 5.6 | Kode Program Implementasi User Equipment dan eNodeB | 51 |
| Gambar 5.7 | Kode Program Implementasi Jaringan LTE pada User Equipment dan eNodeB | 52 |
| Gambar 5.8 | Kode Program Implementasi IP Address dan Internet pada setiap User Equipment | 53 |
| Gambar 5.9 | Kode Program Implementasi User Equipment pada eNodeB | 53 |
| Gambar 5.10 | Kode Program Implementasi IP Address pada X2 Interface dan S2 Interface | 54 |
| Gambar 5.11 | File Video Streaming | 54 |

| | | |
|-------------|--|----|
| Gambar 5.12 | Kode Program Implementasi Video Streaming | 55 |
| Gambar 5.13 | Kode Program Implementasi X2 Handover | 56 |
| Gambar 5.14 | Kode Program Implementasi Perintah Handover | 57 |
| Gambar 5.15 | Kode Program Implementasi menjalankan Aplikasi Video Streaming Pada User Equipment dan Remote Host..... | 58 |
| Gambar 5.16 | Kode Program Implementasi NetAnim..... | 59 |
| Gambar 5.17 | Kode Program Implementasi Flow Monitor..... | 60 |
| Gambar 5.18 | Kode Program Implementasi Grafik Delay | 61 |
| Gambar 5.19 | Kode Program Implementasi Grafik Packet Loss..... | 61 |
| Gambar 5.20 | Kode Program Implementasi Grafik Throughput | 62 |
| Gambar 5.21 | Pengaturan Skenario Pengujian | 62 |
| Gambar 5.22 | Pengujian Simulasi Tanpa Visualisasi | 63 |
| Gambar 5.23 | Pengujian Simulasi Dengan Python | 64 |
| Gambar 5.24 | Perintah Untuk Menampilkan Antarmuka NetAnim | 65 |
| Gambar 5.25 | Antarmuka NetAnim Menampilkan IP Address dan MAC Address | 66 |
| Gambar 5.26 | Pengujian Simulasi dengan NetAnim | 66 |
| Gambar 5.27 | Hasil Perhitungan Pada Flow Monitor | 67 |
| Gambar 5.28 | Perintah Menampilkan Grafik Delay | 68 |
| Gambar 5.29 | Perintah Menampilkan Grafik Packet Loss | 69 |
| Gambar 5.30 | Perintah Menampilkan Grafik Throughput | 70 |
| Gambar 6.1 | Nilai Rata-rata Delay untuk Kecepatan 40 km/Jam, 70 Km/Jam dan 100 Km/Jam | 72 |
| Gambar 6.2 | Nilai Rata-rata Packet Loss untuk Kecepatan 40 km/Jam, 70 Km/Jam dan 100 Km/Jam | 73 |
| Gambar 6.3 | Nilai Rata-rata Throughput untuk Kecepatan 40 km/Jam, 70 Km/Jam dan 100 Km/Jam | 74 |

DAFTAR TABEL

| | | |
|-----------|---|----|
| Tabel 2.1 | Perbandingan penelitian..... | 8 |
| Tabel 3.1 | Hubungan Antara Kedalaman Warna dan Resolusi Warna..... | 24 |
| Tabel 3.2 | Pengelompokan Waktu Tunda berdasarkan ITU-T G.114..... | 25 |
| Tabel 3.3 | Pengelompokan Packet Loss berdasarkan ITU-T G.1010..... | 27 |
| Tabel 3.4 | Pengelompokan Throughput berdasarkan ITU-T G.1010..... | 28 |
| Tabel 4.1 | Konfigurasi IP Address Remote Host | 41 |
| Tabel 4.2 | Konfigurasi IP Address SGW/PGW | 41 |
| Tabel 4.3 | Konfigurasi IP Address X2 Interface dan S1 Interface pada eNodeB | 41 |
| Tabel 4.4 | Skenario Pengujian Pada Mode Frekuensi Division Duplex (FDD) | 47 |