ASSESSMENT OF LTE MAC LAYER UNDER DDOS ATTACKS

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Samatar MOHAMED ALI

Thesis Advisor
Assist.Prof.Dr. Muhammet ÇAKMAK

ASSESSMENT OF LTE MAC LAYER UNDER DDOS ATTACKS

Samatar MOHAMED ALI

T.C

Karabuk University

Institute of Graduate Programs

Department of Computer Engineering

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I certify that in my opinion the thesis submitted by Samatar MOHAMED ALI titled "ASSESSMENT OF LTE MAC LAYER UNDER DDOS ATTACKS" is fully adequate in scope and in quality as a thesis for the degree of Master of Science.

Assist.Prof.Dr. Muhammet ÇAKMAK ....
Thesis Advisor, Department of Electrical Electronics Engineering

This thesis is accepted by the examining committee with a unanimous vote in the Department of Computer Engineering as a Master of Science thesis. January 7, 2022

Examining Committee Members (Institutions)		Signature
Chairman	: Assist.Prof.Dr. Zafer ALBAYRAK (SUBU)	....
Member	: Assist.Prof.Dr. Muhammet ÇAKMAK (KBÜ)	....
Member	: Assist.Prof.Dr. Emrah ÖZKAYNAK (SUBU)	....

The degree of Master of Science by the thesis submitted is approved by the Administrative Board of the Institute of Graduate Programs, Karabuk University.

Prof. Dr. Hasan SOLMAZ ....
Director of the Institute of Graduate Programs

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Samatar MOHAMED ALI

ABSTRACT

M. Sc. Thesis

ASSESSMENT OF LTE MAC LAYER UNDER DDOS ATTACKS

Samatar MOHAMED ALI

Karabük University
Institute of Graduate Programs
The Department of Computer Engineering

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Long-term Evolution (LTE) is a rapidly changing and evolving cellular network technology that allows users to connect to the Internet via mobile phones and other mobile devices. In the cellular LTE network, it is important to manage network traffic and to distribute network resources fairly and efficiently between users. In addition, providing security on the LTE network is an important factor in uninterrupted service quality. Network bandwidth is used uselessly by distributed denial-of-service attacks on cellular networks, mobile devices using the network cannot receive service, and network disconnections cause the network to be disabled.

Scheduling algorithms used in the MAC of the cellular LTE network make an important contribution to network security by performing functions such as data transfer and controlling the cellular radio source. The performance of MAC scheduling algorithms developed for cellular LTE networks is determined by performance parameters such as end-to-end throughput, end-to-end delay, fairness index, and packet delivery rate (PDF).

In this thesis, the performance of MAC scheduling algorithms maximum throughput (MT), blind equal throughput (BET), round-robin (RR), throughput to average (TTA), and proportional fair (PF) running on the LTE MAC layer under DDoS attacks using the NS-3 network simulation platform is compared to end-to-end throughput, end-to-end delay, fairness index, and PDF parameters. According to the experimental results obtained, the TTA algorithm has performed better in ensuring network security than other algorithms

Key Words : LTE, Ns-3 simulation, DDoS Attack, Scheduling algorithms.
Science Code : 92407

ÖZET

Yüksek Lisans Tezi

LTE MAC KATMANININ DDOS SALDIRILARI ALTINDA İNCELENMESİ

Samatar MOHAMED ALI

Karabük Üniversitesi
Lisansüstü Eğitim Enstitüsü
Bilgisayar Mühendisliği Anabilim Dalı

Tez Danışmanı:
Dr. Öğr. Üyesi Muhammet ÇAKMAK
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Uzun Vadeli Evrim (LTE), kullanıcıların cep telefonları ve diğer mobil cihazlar aracılığıyla internete bağlanmasını sağlayan, hızla değişen ve dönüşen hücresel bir ağ teknolojidir. Hücresel LTE ağında, ağ trafiğinin yönetilmesi, ağ kaynakların kullanıcılar arasında adil ve verimli bir şekilde dağıtılması önem arz etmektedir. Ayrıca LTE ağında güvenliğin sağlanması kesintisiz servis kalitesi gereği önemli bir unsurdur. Hücresel ağlarda meydana gelen dağıtılmış hizmet reddi saldırıları ile ağ bant genişliği gereksiz olarak kullanılmakta, ağı kullanan mobil cihazlar servis hizmeti alamamakta ve ağdaki bağlantı kopmaları ağın devre dışı kalmasına neden olmaktadır.

Hücresel LTE ağının orta erişim kontörlü katmanında (MAC) kullanılan zamanlama algoritmaları veri aktarma ve hücresel radyo kaynağını kontrol etme gibi işlevleri yerine getirerek ağ güvenliğinin sağlanmasına önemli bir katkı sunmaktadır. Hücresel LTE ağları için geliştirilen MAC zamanlama algoritmalarının performansı uçtan uca

verim, uçtan uca gecikme, adalet indeksi ve paket teslim oranı gibi performans parametreleri ile belirlenmektedir.

Bu tezde, NS-3 ağ simülasyon platformu kullanılarak DDoS saldırıları altında LTE MAC katmanında çalışan MAC zamanlama algoritmalarından maksimum verim (MT), kör eşit verim (BET), round-robin (RR), eşik ve zamanlama (TTA) ve orantılı adelet (PF) algoritmalarının performansı uçtan uca verim, uçtan uca gecikme, adalet indeksi ve paket teslim oranı parametrelerine göre karşılaştırılmıştır. Elde edilen deneysel sonuçlara göre TTA algoritması diğer algoritmalara göre ağ güvenliğinin sağlanmasında daha iyi bir performans göstermiştir.

Anahtar Kelimeler : LTE, Ns-3 Simülasyonu, DDoS Saldırısı, Zamanlama algoritmaları.

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ABBREVITIONS INDEX

1G	:	First Generation
2G	:	Second Generation
3G	:	Third Generation
4G	:	Fourth Generation
5G	:	Fifth Generation
AQM		Active Queue Management
BET	:	Blind Equal Throughput
CN	:	Core Network
CSG	:	Closed Subscriber Group
DC	:	Dual Carrier
DDoS	:	Distributed Denial of Service
EDGE	:	Enhanced Data for Global Evolution
E-UTRAN	:	Evolved-Universal Terrestrial Radio Access Network
GPRS	:	General Packet Radio Service
HD	:	High Definition
HSPA+	:	Evolved High Speed Packet Access
HSS	;	Home Subscriber Server
LTE		Long-Term Evolution
IP	:	Internet protocol
MAC	:	Medium Access Control
MME	:	Mobility Management Entity
MMS	:	Multimedia Messaging Service
MT	:	Maximum Throughput
NS	:	Network Simulation
PCRF	:	Policy and Charging Rules Function
PDCP	:	Packet Data Convergence Protocol
PDF	:	Packet Delivery Fraction
PF	:	Proportional Fair
P-GW	:	PDN Gateway

PLRT	:	Packet Level Restraining Technique
QoS	:	Quality Of Service
RLC	:	Radio Link Control
RNC	:	Radio Network Controller
RR	:	Round-Robin
RRC	:	Radio Resource Control
SAE	:	System Architecture Evolution
S-GW	:	Serving Gateway
SMS	:	Short Message Service
TE	:	Terminal Equipment
TTA	:	Throughput To Average
UE	:	User Equipment
UICC	:	Universal Integrated Circuit Card

PART 1

INTRODUCTION

1.1 OVERVIEW

There were several stages in the development of mobile networks [1]. The first generation of mobile networks is the 1G network. It was made possible by using analogue transportable phones, mostly found in automobiles. Mobile communication has turned into digital signals with the Second Generation (2G). With 2G, innovations such as high voice quality, encryption, and transmission of message data have emerged. General Packet Radio Service (GPRS-General Packet Radio Service) 2.5G and EDGE (Enhanced Data for GSM Evolution) 2.75G of data transfer in mobile communication started [2].

With the Third Generation (3G), known as the Universal Mobile Telephone System (UMTS-Universal Mobile Telecommunications System), fast data transmission, video calls, and mobile internet access gained speed. High Speed Packet Access (HSPA-High Speed Packet Access), also known as 3.5G, and Advanced High Speed Packet Access (HPSA+-Evolved High Speed Packet Access), also known as 3.75G, provide low latency and high-speed data for faster internet [3].

4G or LTE (Long Term Evolution) gives users the opportunity to surf at a very high speed. With a high speed, 4G can transfer heavy files, watch videos in HD, "live-stream", etc.

5G continues to develop areas such as the Internet of Things (IoT), smart homes, driverless cars, high-definition and very fast data transfer, virtual reality, Industry 4.0 and remote surgery applications. To satisfy the growing resource requirements of quickly evolving cellular networks, the cellular network operator must ensure the highest possible Quality of Service (QoS) for a variety of applications, including voice, video, multimedia, and the increasingly prevalent IoT [4]. Increasing demands in cellular networks such as high-quality video and audio streaming, high-speed data download, access to cloud-based applications, smart home, and autonomous vehicle control, rapid access to augmented and virtual reality applications are the main factors in the development of cellular networks. In the face of these changes, the management of resources in cellular networks gains more importance. For this reason, cellular network operators, industry organizations that develop network equipment, and researchers propose new solutions for the development of cellular network systems and improving their performance [5].

The necessity of distinguishing divergent packets on telecommunications networks became apparent with the emergence of packet scheduling, which is synonymous with bandwidth sharing. The requirement for efficient packet scheduling and bandwidth sharing has resulted in a significant investment of time and effort in these areas during the last decade [6]. There are many networks simulation software used for research and development of new algorithms. This network simulation software can be divided into open source and commercial. The developer communities behind open-source software provide great support for the software, the professional developer team behind commercial software supports its users in software-related help and documentation. NS-3 (Network Simulator 3) is an open-source network simulator for network research with a large community of volunteer developers behind it.

1.2 PURPOSE OF THE STUDY

The primary concern of this thesis is the assessment of LTE MAC layer under DDoS attacks. This study proposes using scheduling algorithms, especially five scheduling algorithms (MT, TTA, BET, RR, PF), to know the most appropriate method to increase the system efficiency of the scheduling algorithms working in the MAC layer for the solution of congestion issues in the cellular LTE network.

1.3 LITERATURE REVIEW

The literature review on DDoS attack issues in the LTE network and some others networks, as well as the effectiveness of scheduling methods, is presented in this part. There are numerous scheduling algorithms (BET, TBFQ, TTA, and PSS) that were examined in [7] for throughput, latency, and fairness in terms of providing radio resources. There are two schedulers that provide the best performance in terms of user latency, throughput, and fairness: the TD-TBFQ and FD-TBFQ schedulers.

The Vienna LTE-A System Level Simulator was used by Marini et al [8] to test the following schedulers in LTE systems: Round Robin, Best CQI, Proportional Fair, and Resource Fair are all terms used to describe how a competition is conducted. According to the results, the Best CQI scheduler provides the best high throughput and average bandwidth efficiency. The MaxMin method, on the other hand, improves the fairness of user equipment and increases edge throughput.

Three well-known uplink schedulers (MT, FME, and RR) are investigated and compared in this paper [9]. Simulated results suggest that the RR algorithm consistently generates the lowest PLR and the highest throughput for video and VoIP traffic.

Two scheduler algorithms were proposed by Sharma et al. [10]. (PF, MT). The NetSim network analyzer is used to examine the throughput and hold-off times between the selected schedulers. The suggested approach in this study seeks to improve throughput and reduce hold-off time for continuously streaming for practical uses while maintaining the QoS standards.

Authors in this study [11] analyzed and compared MT, BET, and PF in Network Simulator-3 (NS-3). When a large number of mobile devices, FD-MT has a high average TCP throughput than its older TD variant. TCP throughput and variance in FD-BET are similar to that of TD BET when there are few users.

Raissi et al. [12], investigated the performance of a variety of scheduling algorithms, including RR, PF, PS, TTA, MT, and BET. These simulations demonstrated that the RR algorithm is the optimal scheduler in terms of throughput, delay, packet loss rate, and fairness.

In [13], the authors compared the performance of MAC scheduling algorithms in IEEE 802.15 using OMNET++.

Authors in this study [14], compared performance of LTE PG-W and remote host. They showed the best performance of queue management algorithms in connections (remote host and PG-W).

The problem of Distributed Denial of Service (DDoS) attacks in LTE was studied in in [15], a load balancing method was offered as a protection. Increased traffic and network performance can be achieved through the use of the approach outlined. The distribution of resources becomes more efficient. There's no need to set up any additional backup infrastructure when using the method demonstrated here, which is straightforward and only requires local activation. The technique enhances network operation and maintenance when the threshold for handovers is correctly established according to the scenario.

The signaling control plane of next-generation mobile networks was overloaded in [16] by a novel developing DDoS assault that took use of the MTC paradigm's vulnerabilities. They suggested a new detection paradigm based on the recurrence features of the Markov chain. In addition, the suggested detection method is the first one to take advantage of the recurrence of Markov chain states to identify botnets in a DDoS-victim network.

According to [17], this paper focuses on increasing VOLTE-VOIP network security and presents a number of ideas to improve network security. The purpose of this assault is to prevent customers from using IP spoofing and false messages, which slow down the transfer of voice data packets. The PLRT (Packet Level Restraining Technique) approach locates the DDOS attack source and prevents that node from connecting with the entire network. The proposed method outperforms DDOS attacks and produces better results.

In [18], authors compared the active queue management algorithms performance in the LTE networks.

Active Queue Management Algorithms for Mobile Networks have been compared in this study [19], as well as the development of enhanced versions of these algorithms using various approaches and techniques.

Ref [20], researchers focused on the security issues of tactical mobile ad hoc networks. A cluster mobility model has been presented to complement the battlefield practical application because of its multi-hop, energy limited, powerful self-organization, high mobility, and other qualities. In this technique, DDoS attacks are undertaken on tactical mobile ad hoc networks in both standby and moving circumstances.

In [21], the LTE mobile network model has several serious security flaws. Security threats are analyzed in terms of a DDoS signaling flood recorded by dysfunctional applications against with a mobile network. An ECN-based approach has been presented as a means of preventing congestion in diameter interfaces. According to an NS-2 simulation, the service quality of the diameter transport interface was improved by reducing needless packet drops.

1.4 ORGANIZATION OF THESIS

This thesis evaluated the performance of MAC scheduling algorithms under DDoS attacks. This thesis consists of six chapters, and the rest of the thesis is organized as follows: Chapter 2, a brief explanation of LTE Network in this section. Chapter 3-5 includes the proposed methodology for the work of this thesis, which is also 3 parts: MAC Scheduling, DDoS attack, and Network Simulators used in this study. Chapter

6 deals with the results achieved and discuss them. Chapter 7 includes both the conclusion and future work.

PART 2

LTE NETWORK

2.1 OVERVIEW

The idea of a project to develop LTE technology is led by the 3GPP standardization organization to draft the technical standards for the future fourth generation of mobile telephony. This technology aims to allow data transfer at very high speed, with a greater range, a higher number of calls per cell (area in which a mobile transmitter can enter contact with terminals) and a latency time weaker. In theory, it achieves speeds of the order of 50 Mb/s in uplink and 100 Mb/s in downlink, shared between mobile users within the same cell. For operators (who have the most important part to support this technology), LTE involves modifying the core of the network and the radio transmitters. We must also develop suitable mobile terminals.

2.2 LTE NETWORK ARCHITECTURE

LTE is founded on the principle of the System Architecture Evolution (SAE). It is composition of the Evolved-Universal Terrestrial Radio Access Network (E-UTRAN) and the Evolved Packet Core [22]. Any cellular network's architecture is its skeleton. It is a cellular technology's infrastructure. In comparison to 3G, LTE has a more modern architecture, which results in greater efficiency. To have a comprehensive understanding of this technology, we must examine its architecture in detail. It is generally split into three blocks: UE, E-UTRAN, and EPC. The following are the functions of these elements: EUTRAN is a system made up of a number of eNodeBs that are linked together by an interface (X2 interface). The eNodeB is responsible for responsibilities that are shared by the RNC and the eNodeBs. The eNodeBs were created to minimize the radio interface process's latency. They communicate with the packet switched (PS) core network via the S1 interface. Figure 1 is a visual representation of it [23].

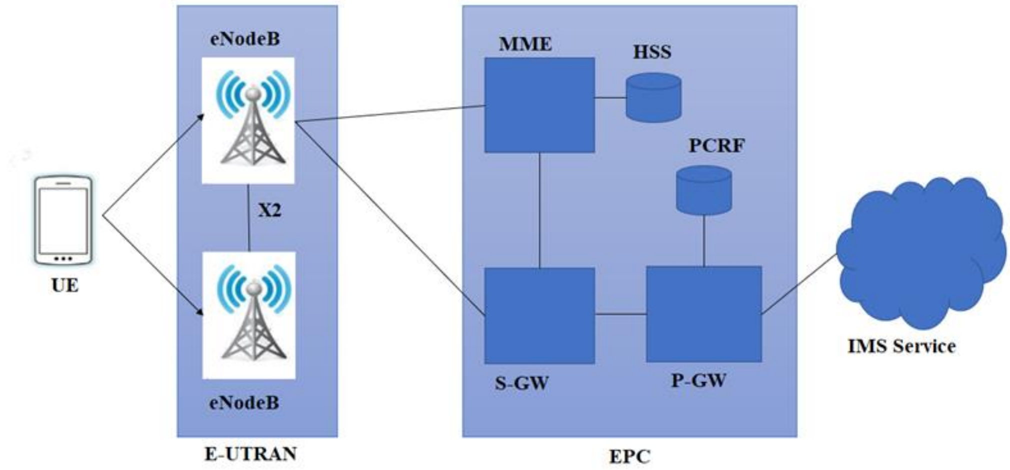

Figure 2.1 LTE Architecture [21],[22]

2.2.1 User Equipment (UE)

User Equipment (UE) is defined by 3GPP Long Term Evolution (LTE) as any device used directly by an end user to communicate with the base station node B. (eNodeB). Mobile phones, computers with a mobile broadband adapter, or any other device can be used for this purpose. The inside architecture of UMTS and GSM mobile devices is identical to the internal architecture of LTE, which is a major difference. TM, Terminal Equipment (TE), and the Universal Integrated Circuit Card (UICC) are all components of the mobile equipment (UICC).

2.2.2 Access Network (E-UTRAN)

The air interface to UE is provided by only one type of node in E-UTRAN, the eNodeB. The X2 interface is used to connect eNodeBs to each other, and the S1 interface is used to connect MMEs and S-GWs. Multiple MMEs and S-GWs can all be connected to a single eNodeB. S1-flex refers to this capability, which gives flexibility and dependability. Figure 2.2 illustrates the several eNodeB connection possibilities [24].

Radio transmission to and reception from the UE are handled by the eNodeB. The RNC node is not present in the LTE network, as you may have seen. The eNodeB, on the other hand, contains RNC functionality. Radio resource management (including admission control), radio bearer control, user data scheduling, and control signalling over the air interface are all part of this. Furthermore, the eNodeB uses the air interface to conduct ciphering and header compression [24].

The X2 interface, which is comparable to the Iur interface between RNCs in a WCDMA network, is used to connect eNodeBs. However, because e-UTRAN provides an anchor point and functionality, the X2 interface will only connect eNodeBs to neighbouring cells. The X2 does not include RNC drift functionality; instead, it has packet forwarding and relocation functions [24].

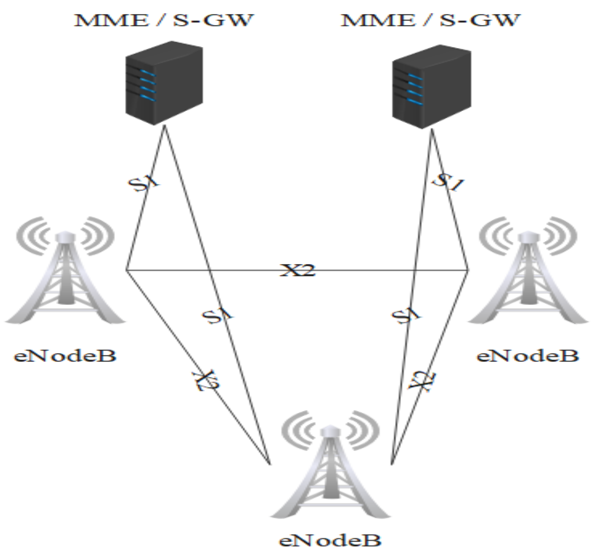

Figure 2.2 E-UTRAN with S1-flex interface [24]

The S1 interface is used to link eNodeB to the core network. In a 3G system, the S1 interface is analogous to the Iu-ps interface. The S1 and Iu-ps user planes are both IP-based transport tunnels that are unconcerned about the content of the packets delivered. The EPC or eNodeB injects IP packets from the end user into the S1 IP tunnel and retrieves them at the other end (eNodeB or EPC). The S1 interface was designed to allow eNodeB to communicate with numerous MMEs and S-GWs. If one of the EPC nodes fails, another EPC node can take over the missing traffic with S1-flex.

Furthermore, this allows for network dynamic scaling, as EPC nodes may be added based on traffic demands rather than coverage expansion [24].

2.2.3 Core Network (CN)

The CN (also known as the EPC in SAE) uses full IP technologies, based on Internet protocols for signaling, voice, and data transport. This core network allows interconnection via routers with remote eNodeBs, networks of other mobile operators, fixed telephone networks, and the Internet. EPC consists of S-GW, P-GW, MME and HSS. It serves as a bridge between the EPC and the external networks, which comprise a subset of IP Multimedia Core Network Subsystem (IMS) [23].

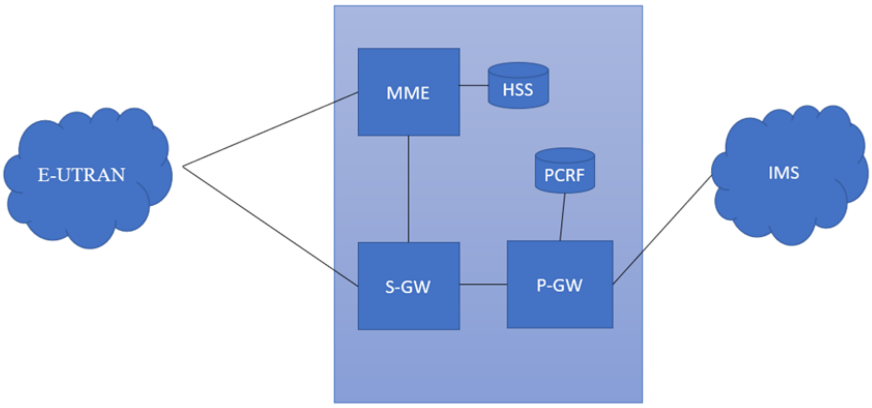

Figure 2.3 EPC Connection with RAN EPC architecture

2.2.3.1 Serving Gateway (S-GW)

This is the network component that connects the improved packet core to the radio side. Incoming and outgoing IP packets are routed through this device, which benefits the user equipment. It serves as a hub for intra-LTE mobile handovers between two eNodeBs. The PDN gateway is connected to it virtually via another gateway [23].

2.2.3.2 PDN Gateway (P-GW)

P-GW connects the improved packet core to the external IP network via the PDN Gateway. The PDN gateway acts as a conduit for packets to and from the public networks. Additionally, it assigns IP addresses to users and charges them based on their usage [23].

2.2.3.3 Mobility Management Entity (MME)

This network entity is responsible for user mobility signaling as well as E-UTRAN access security. It functions as a tracker, tracking and paging user equipment while it is idle [23].

2.2.3.4 Home Subscriber Server (HSS)

This serves as an information register, containing all subscriber-related data for that particular eNodeB's local subscribers. Mobility management is also supported [23].

2.2.3.5 Policy and Charging Rules Function (PCRF)

This entity provides the rules for charging user flows and makes it possible to ask the PDN-GW to establish, modify and release “dedicated bearers” based on the quality of service (QoS) desired by the use.

2.3 LTE LAYERS

The LTE link layer protocols are simpler and more efficient than their UTRAN counterparts, resulting in lower delay and lower overhead. The most recent LTE protocol design is the product of a rigorous cross-layer strategy in which the protocols interact efficiently with one another. It consists of the following layers.

2.3.1 Physical

The physical layer provides access to the higher layers via transport channels. The physical layer serves as a conduit for data transfer between the MAC and higher layers. A radio link is a connection between a mobile station and a base station cell that is bidirectional. The physical layer control channel of each radio connection is linked to one or more traffic channels (DPCCH) [24]. The MAC and RLC sublayers of the data-link layer govern the physical layer. Transport channel management is accomplished by MAC, whereas flow control is accomplished by RLC. The physical layer and all of its actions are overseen by RRC [24].

2.3.2 Radio Resource Control (RRC)

It is used to perform the control function of the radio interface. RRC is connected to the MAC and PHY layers in order to configure them via control access points. It provides the following functions:

- Broadcasting and decoding of AS and NAS level System Information on the cell for all UEs in standby mode present on the cell, including cell access, measurement, and standby reselection parameters.
- Sending and receiving paging, for setting up a call to a UE in standby mode, for informing UEs in the cell that the System Information is modified, or for alerting them in case of force majeure.

2.3.3 Packet Data Convergence Protocol (PDCP)

PDCP provides security and data transfer functions:

- Header compression.
- Encryption of data and RRC signaling.
- Integrity protection of RRC signaling.
- Duplicate detection and removal (PDCP data unit received twice);

2.3.4 Radio Link Control (RLC)

It provides the data link control functions of layer 2 of the OSI model (Data Link Control): The RLC standard is provided by 3GPP. RLC SDUs are framed by the RLC layer to the size specified by the lower MAC layer. RLC PDUs are constructed by segmenting and/or concatenating RLC SDUs, while RLC SDUs are reconstructed by reassembling RLC PDUs [25]. It provides the data link control functions of layer 2 of the OSI model (Data Link Control):

- Detection and retransmission of missing PDUs (in acknowledged mode) allowing error recovery.
- Resequencing of PDUs to ensure SDU scheduling at the upper layer (PDCP).
- Use of transmitting and receive windows to optimize data transmission.

2.3.5 Medium Access Control (MAC)

It allows access and adaptation to the transmission medium through the following functions [26],:

- Random access mechanism on the uplink.
- Error correction by HARQ retransmission when receiving a negative HARQ acknowledgment.
- Dynamic and semi-static radio resource allocation (scheduling).
- Maintenance of synchronization on the uplink.
- Prioritization of uplink flows.

PART 3

MAC SCHEDULING ALGORITHMS

The scheduler is a feature of the MAC layer that manages resource allocation to users [8]. The main objective of scheduling is to coordinate user access to shared transport data channels [27]. The following algorithms can be used by the scheduler to allocate resources.

3.1 ROUND ROBIN (RR)

One of the earliest algorithms which NS-3 allowed, It's also the most basic. This method operates similarly to a ration, in that time slots are distributed evenly among all processes in a round robin method, and all processes are addressed equally. This algorithm is completely free of starvation. Due to the fact that extra flows cannot be allocated inside the same subframe, they will be distributed in a cyclical pattern over different subframes. The MCS for each user will be determined based on the channel quality indicator (CQI) received [28].

RR scheduler is a channel unaware scheduling method that is simple and quick to implement. In this scheduling method, each UE is assigned an equal amount of RBs. The scheduling is entirely dependent on the available RBs, and each UE's RBs are grouped into many RBs throughout the scheduling process.

3.2 PROPORTIONAL FAIR (PF)

PF scheduling allows for high resource block efficiency while maintaining high decency between system streams.

According to this algorithm, the UE receives t more resources when its channel quality is superior to that of the average channel over time. Mathematically, the PF can be explained as follows: Let's call the users i,j, the subframe index t, and the resource blocks k. Let's define modulation coding sequence (MCS): There are typically several resource blocks B in use, so $M_{i,k}$(t)for the user i and for tat can serve, let S(M,B) be the amount in bits. The $R_i(\mathrm{k,t})$ in bit/s is given as the user i on the resource block k at subframe t [28]

$$R_i(\mathrm{k,t}) = \frac{S(M_{i,k}(\mathrm{t}),1)}{\tau} \tag{3.1}$$

where the τ's TTI duration is equal to the TTI duration. At the start of each subframe t, the resource block is assigned to each user. The index $i_k(t)$ to which RB k is assigned at time t is calculated as follows [28]:

$$i_k(t) = argmax_{j=1,\dots,N}\left(\frac{R_j(\mathrm{k,t})}{\tau}\right) \tag{3.2}$$

where $T_j(t)$ denotes the user j's previous throughput performance. A user might be assigned to a variety of RBGs, that can be nearby or not adjacent, depending on the existing channel situation and past throughput $T_j(t)$ performance, using the aforesaid scheduling technique. The following exponential moving average approach can be used to determine historical throughput performance at the end of the subframe t [28]:

$$T_j(t) = (1-\frac{1}{\alpha}+T_j(t-1)+\frac{1}{\alpha}T_j(t) \tag{3.3}$$

The real throughput is being expressed as $T_j(t)$ attained by the user in the subframe t, while α is represented as the exponential moving average's time constant. The process for determining $T_j(t)$is as follows. First, we need to figure out which MCS is being utilized by user j [28]:

$$M_j(t) = min_{k:i_k(t)=j}M_{j,k}(t) \tag{3.4}$$

The total number of $B_j(t)$ of RBs assigned to user j is then calculated [28]:

$$B_j(t) = |\{\mathrm{k}: \ i_k(t) = j\}| \tag{3.5}$$

where $|\cdot|$ denotes the set's cardinality; finally,

$$T_j(\mathrm{t}) = \frac{S(M_j(\mathrm{t}), B_j(\mathrm{t}\,)}{\tau} \tag{3.6}$$

3.3 MAXIMUM THROUGHPUT (MT)

MT is a QoS unaware or channel aware scheduler. This scheduling algorithm prioritizes resources to the user with the best channel conditions. It aims at maximizing the overall throughput by assigning each Resource Block (RB) to the user that can achieve the maximum throughput in the TTI. MT is very unfair to the users with poor channel conditions because their expected achievable throughput is low as well as their metric. Thus, the users further away from the base station are not served so frequently and will suffer from starvation

$$R_i(\mathrm{k}, \mathrm{t}) = \frac{S(M_{i,k}(\mathrm{t}), 1)}{\tau} \tag{3.7}$$

τ is the TTI time, which can be indicated. Every user is given the RB at the start of each subframe t. The index $i_k(t)$ whereby RB t is allocated at any given time can be calculated as follows:

$$i_k(t) = argmax_{j=1,\dots,N}(R_j(\mathrm{k}, \mathrm{t}) \tag{3.8}$$

When there are multiple UEs with the same attainable rate, the actual configuration usually chooses the first UE produced in the program. MT, despite its ability to supply higher cell throughput, never guarantee fairness to UEs experiencing poor channel conditions.

3.4 THROUGHPUT TO AVERAGE (TTA)

TTA is a scheduler that is oblivious to QoS or channels. It is a combination of maximum throughput and a professional fair scheduler.

The normalization factor for the achievable throughput on the considered RB is the feasible throughput throughout the entire bandwidth in the present TTI. It quantifies the benefit of allocating a specific RB to each user, ensuring that the best RBs are assigned to each user. Indeed, it is clear from its meter that the higher a user's overall predicted throughput is, the lower its metric on a single resource block will be. This scheduler makes advantage of channel awareness to ensure that each user receives a minimum level of service. This scheduling algorithm is thought to be between MT and PF. The following are the metrics that were used in this algorithm:

$$i_k(t) = argmax_{j=1,\ldots,N}\left(\frac{R_j(\mathrm{k},\mathrm{t})}{R_j(\mathrm{t})}\right) \tag{3.9}$$

The possible rate for a user on resource block k at subframe t is represented as $R_i(\mathrm{k},\mathrm{t})$in bit/s. The process for calculating the results has already been addressed in the MT and PF. Meanwhile, the possible rate for an i^th user at subframe t is denoted by $R_i(\mathrm{t})$ in bit/s. How to acquire MCS is the difference between those two different possible rates. MCS may be computed using sub-band CQI for $R_i(\mathrm{k},\mathrm{t})$, while $R_i(\mathrm{t})$ can be calculated using wideband CQI. Due to the fact that scheduling is the only factor that affects the RBG's possible pace, FD can only use the TTA scheduler.

3.5 BLIND EQUAL THROUGHPUT (BET)

BET doesn’t consider the channel condition while allocating resources; instead, BET allocates the same amount of resources to all UEs in the same eNodeB. A channel-aware scheduling method, this one differs from Mt and TTA. Wideband CQI is used in both FD and TD BET to make scheduling decisions. It's easiest to understand BET's decision in this regard by stating:

$$i_k(t) = argmax_{j=1,\ldots,N}\left(\frac{1}{T_j(\mathrm{t})}\right) \tag{3.10}$$

where the user j can express previous throughput performance as $T_j(\mathrm{t})$ and calculate it using the same approach as the PF scheduler. In the TD flavour of the algorithm, the TD-BET scheduler picks the UE with the greatest potential metric and distributes all RBGs to this UE. The scheduler selects the UE with the lowest average throughput in the past in the frequency domain flavour of the blind average throughput (FD-BET) for each TTI (largest priority metric). The scheduler then assigns one RBG to this UE, calculates its projected throughput, and compares it to other UEs' previous average throughput $T_j(\mathrm{t})$. The scheduler will allocate this UE the RBG until the projected throughput $T_j(\mathrm{t})$ of all UE is better than the previous throughput $T_j(\mathrm{t})$. The scheduler will next apply the same procedure to assign RBG to a fresh UE with the lowest past average throughput $T_j(\mathrm{t})$, and this will continue until all RBGs have been assigned to UEs. The basic idea behind this approach is that the scheduler strives to achieve equal throughput among all UEs in the most efficient manner feasible in each TTI.

PART 4

DISTRIBUTED DENIAL OF SERVICE (DDoS)

4.1 OVERVIEW

DDoS is coordinated attacks by a malicious user(s) on a resource by attacking it continuously with high-rate lawful request packets in a short period of time, which eventually takes down the resource and makes it unavailable for legitimate users. It's a multi-source attack against a single target. This renders a DDoS attack fatal and difficult to control. Smurf attacks are the simplest form of DDoS. Using this technique, a single host sends out several echo requests to other hosts on the network [29]. The aim of the DDoS attack is specified in each echo request. DDoS attacks are the hardest to respond against, and organizations cannot use any typical defense measures to use it. Due to the fact that DDoS assaults are designed to look like normal traffic, but the number of attacks has increased rapidly. In Fig. 4.1, a DDoS assault is illustrated as an attacker employs a large number of Zombies to amplify the attack on the victims.

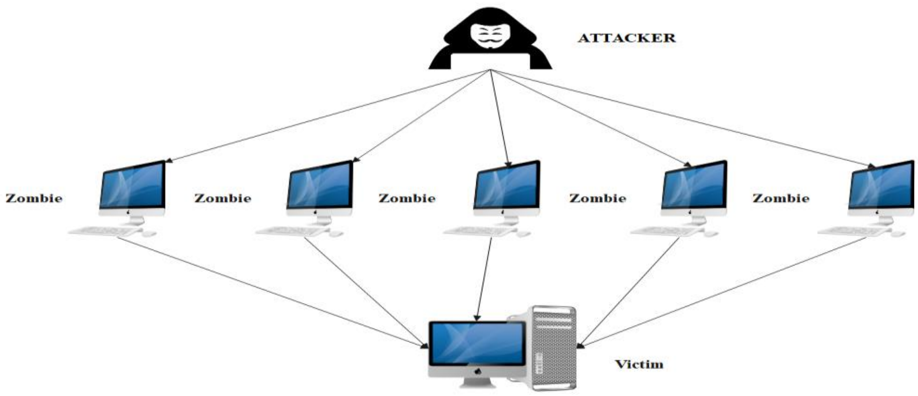

Figure 4.1 Typical of DDoS attack [30]

4.2 TYPES OF DDOS ATTACKS

DDoS attacks can be conducted in one of the following ways to infiltrate a target.

4.2.1 UDP Flood

In the case of UDP, no connection is created between the transmitter and recipient before to transfer of data. It is unable to detect packet loss while data transfer and cannot deliver an error message in that regard. One of UDP's main advantages over TCP is the speed at which data is transmitted. Attackers can, however, use UDP packets to launch UDP flood assaults, such as high bandwidth attacks, on their target network or infrastructure. Figure 4.2 shows how the victim's computer system is slowed down and eventually fails as a result of a massive UDP flood being sent to random ports on victim PC [30].

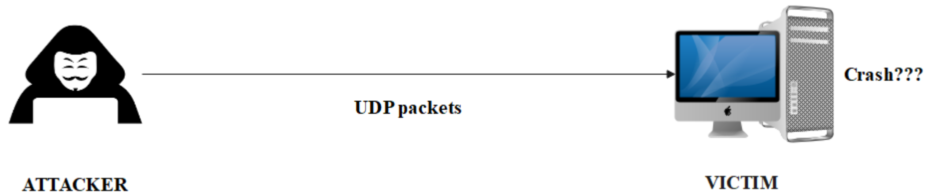

Figure 4.2. UDP Flood attack [30]

4.2.2 TCP SYN Flood

Once data transmission can begin in a TCP connection, the client and server must first establish a connection. TCP three-way handshake is the name given to this process. In order to connect to the server, the client must send a SYN request to the server, which the server will respond to with a SYN-ACK message, and the connection is formed. However, if the attacker repeatedly transmits SYN packets to different ports on the particular server using a false IP address, the usual TCP three-way handshake will change into a TCP SYN flood, as seen in Fig. 4.3. SYN packets are constantly being received, but there is no response from the server to authenticate the clients. This can lead to the server being unable to close the connection (the connection remains open) [30].

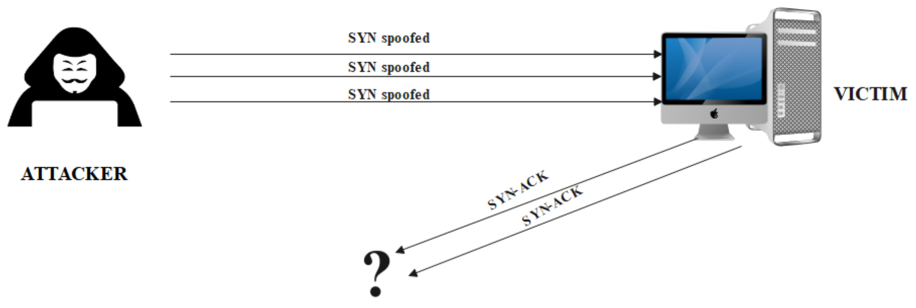

Figure 4.3 TCP SYN Flood attack [30]

4.2.3 Ping of Death

The total size of an IP packet, including headers, is 65535 bytes. Because ping packets greater than the maximum size may violate the Internet Protocol (IP), computer systems were never designed to handle them. Attackers typically send out fragmented, compromised packets from their end. It's possible that the target system may rebuild the fragment, however the packet is too large, which will cause memory overflows and other system issues, including crashes. It's necessary to rapidly counterfeit the attacker's details with Ping of Death, making it a successful attack. Furthermore, the Ping of Death attack does not require the attacker to have any knowledge of the victim's computer other than its IP address [30].

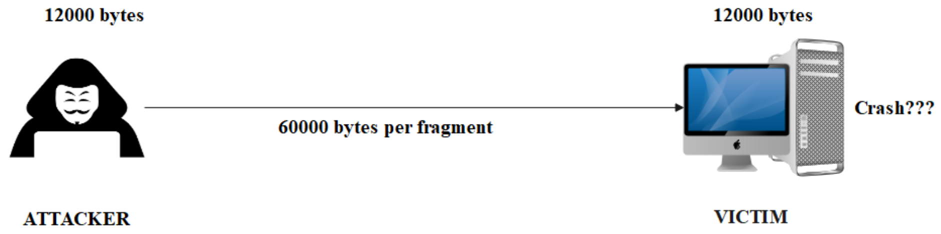

Figure 4.4 Ping of Death attack [30]

4.2.4 Smurf

In order to conduct the Smurf assault, the victim computer is bombarded with massive numbers of ICMP packets as depicted in Figure 4.5. To successfully carry out a Smurf attack, there are five steps. An attack by Smurfs can result in a company's servers being down for days, customers being dissatisfied, and intellectual property being stolen. Even if an attacker just uses a little amount of ping packets to initiate the assault, many Smurf attacks include rockets that allow them to construct a backdoor for simple system access [30].

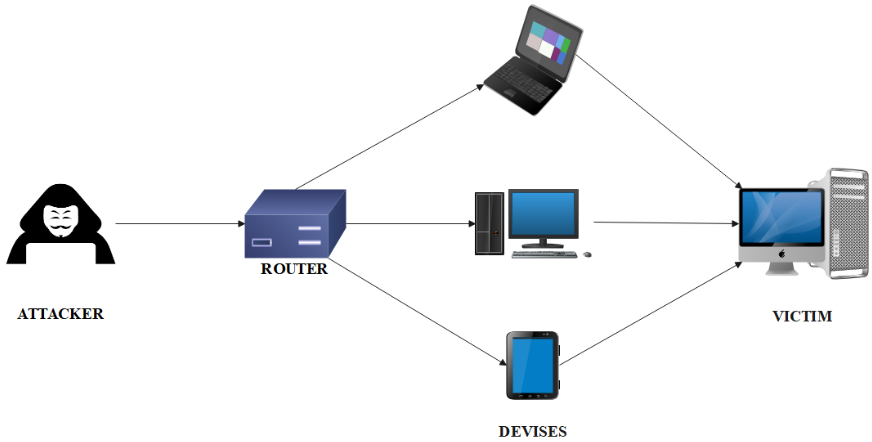

Figure 4.5 Smurf attack [30]

PART 5

NETWORK SIMULATORS

Network simulation is certainly one of the most frequently adopted evaluation methods in the field of computer networks [31]. It's also known as "network emulation" refers to the usage of a simulation program in connection with real applications and services in order to examine end-to-end performance on the computer of the end-user [32]. It is used to analyze, create, simulate, and evaluate the performance of various network theories and hypotheses in a variety of settings, including academic research and industry development [33]. It's a crucial part of network research [34].

5.1 SIMULATORS AND THEIR PROPERTIES

There are a lot of different types of network simulators available, including NS-3, Objective Modular Network Testbed (OMNET++), Optimum Network Performance (OPNET), and JSI, among others.

5.2 OMNET++ SIMULATOR

The OMNeT++ platform is a C++ based simulation platform [35]. It is a discrete event simulation environment that is open source, component-based, modular, and architecture-agnostic. It is accessible for academic and non-commercial use at no fee. Its core application field is network simulation, but because of its general and flexible architecture, it may also be used to simulate complex IT systems, queuing networks, and hardware architectures [32]. GNU Public License-like freedoms are available, but exclusively in non-commercial contexts. Unix and Windows systems are supported by OMNET++'s versions. Using a component-oriented methodology that encourages the creation of reusable models, it was built from scratch As a result, OMNET++ provides a broad GUI and intelligence support [33].

5.3 OPNET SIMULATOR

This is a fantastic tool for working with networks that have many devices and traffic flows or networks where even the slightest modification could be disastrous. Administrators can use several tools in OPNET to examine their networks and plan for future implementations. OPNET promises to be the industry's fastest simulation engine. Simulators for both wired and wireless networks are included. Additionally, it offers several wired/wireless protocol and manufacturer device types with source code and supports object-oriented modelling of components [36].

5.4 NS-3 SIMULATOR

The development of the NS-3 is based on the development of the NS-2. It is primarily utilized in the fields of education and scientific research. It has a highly sophisticated capability that allows it to analyze multiple networks and protocols. NS-3 outperforms the competition in wireless network environments [34]. C++ and python are used to write it. New features and support for parallel simulation are included in the ns-3.1x release. In addition, ns-3 network simulations can be written entirely in C++, with some portions of the code being written in Python as well. For both emulation and simulation, the socket-based ns-3 platform enables the use of sockets. A pcap trace can be generated to aid in debugging. Standard tools like Wireshark can read trace files and analyse network traffic. Ns-3's realistic setting and well-organized code make it a great learning tool [37].

5.5 J-SIM SIMULATOR

The network simulator J-Sim (originally JavaSim) is written in Java. It's based on the component-based software model, Autonomous Component Architecture (ACA) [35], [32]. Additionally, it provides precise packet traces and several levels of abstraction for measuring network performance. It has its own set of advantages and disadvantages. NetSimis is offered in both Standard and Academic editions, and both are built on a common architectural framework of high-level architecture and code. Overall, NetSim is an outstanding product that not only has a wide range of applications but also is extremely well-built and has a wide range of unique capabilities found nowhere else [31]. Scripting languages like Perl, Tcl, and Python can be used with JSim thanks to its scripting interface. [33].

5.6 COMPARISON OF NETWORK SIMULATORS

Table 5.1 Comparison of simulators based on general information [31]

Name	**License Type**	**Language**	**Supported Operating System**	**GUI Support**	**Ease of Use**
OMNET++	Open source (for study and research	C++	Windows XP or Lat-er, Linux, Mac OS X,	Yes	Easy
OPNET	Commercial	C and C++	Windows XP, Vista, 7 & Windows NT 4.0.	Yes	Easy
Ns-3	Open source	C++and Optional Python Bindings	GNU/Linux,FreeBSD, Mac OS X, Win-dows XP, Windows Vista & Windows 7.	Yes	Moderate
J-SIM	Open source	Java	Windows XP, Vista & 7, MAC OS X, Linux.	Yes	Easy

OMNeT++ is gaining popularity in the academic and industrial world. It also has a powerful graphical interface. However, it does not have as many external models and user bases as the NS-3.

Besides being a commercial simulation software, OPNET offers a complete simulation solution to the needs of industrial researchers who want to quickly create reliable simulations. Looking at the simulation descriptions and studies, it can be concluded that NS-3 and OMNeT++ are the best choices for research.

The NS-3 is the most widely used network simulator in academic research, however its architecture is rather sophisticated. By properly developing and controlling a sophisticated network topology and generating visual simulation results, it becomes advantageous. Furthermore, there are numerous resources for the problems experienced due to the high number of user groups and developers [38]. Because it is open source and open to development, the NS-3 network simulation software was used to design the LTE network and test the sheduling algorithms in this thesis.

PART 6

RESULTS & DISCUSSION

6.1 NETWORK MODEL AND SIMULATION PARAMETERS

The LTE design is based on the specifications in Tab. 6.1. The number of UEs is between 10-100 Bots, while the number of eNodeB is one Macrocell. The data rate between the IMS node and the EPC nodes has been set to 100 Gbps. The package size is 1500 bytes. The queue size ranges between 1020 and 51200 bytes. The wired connection has a speed of 100 Mbps. The transmission mode employed by eNodeB is MIMO. TCP NewReno is a type of TCP traffic. RandomWalk2D is the mobility type of the users. The data rate of the interconnection between the EPC node and the eNodeB node is 100 Gbps, with a TTI of 10-50.

Table 6.1. Simulation parameters

Simulation Parameters	**Value**
Number of Botnets	10-100
Number of eNodeB	1 Macrocell
Packet Size	1024 Bytes
Application Date Rate	100 Mbps
Queue Size	1020-51200 bytes
Data Rate	100 Gbps
TTI	10-50 ms
Wired Link Capacity	100 Mbps
Application Traffic	TCP
eNodeB Transmission Mode	MIMO
eNodeB antenna	Parabolic Antenna
TCP Traffic Type	TCP New Reno
Mobility	Random Walk 2D
Total Simulation Time	100 s
Application Start Time	From 0.1 s
Application Stop Time	100 s

6.2 LTE NETWORK APPLICATION MODE

NS-3 module's LTE-EPC Simulator LENA has been developed. LTE and EPC are both included in this model. End-to-end IP communication can be simulated using the EPC model's tools. Multiple eNodeBs can be connected to a single SGW/PGW node via SGW and PGW. A typical LTE model can be used to evaluate the scheduling methods. The LTE network concept is illustrated in Figure. 6.1, which includes 100 botnets, a single eNodeB, S-GW, and P-GW nodes, as well as an internet node for connecting to the IP Multimedia Subsystem (IMS) and services.

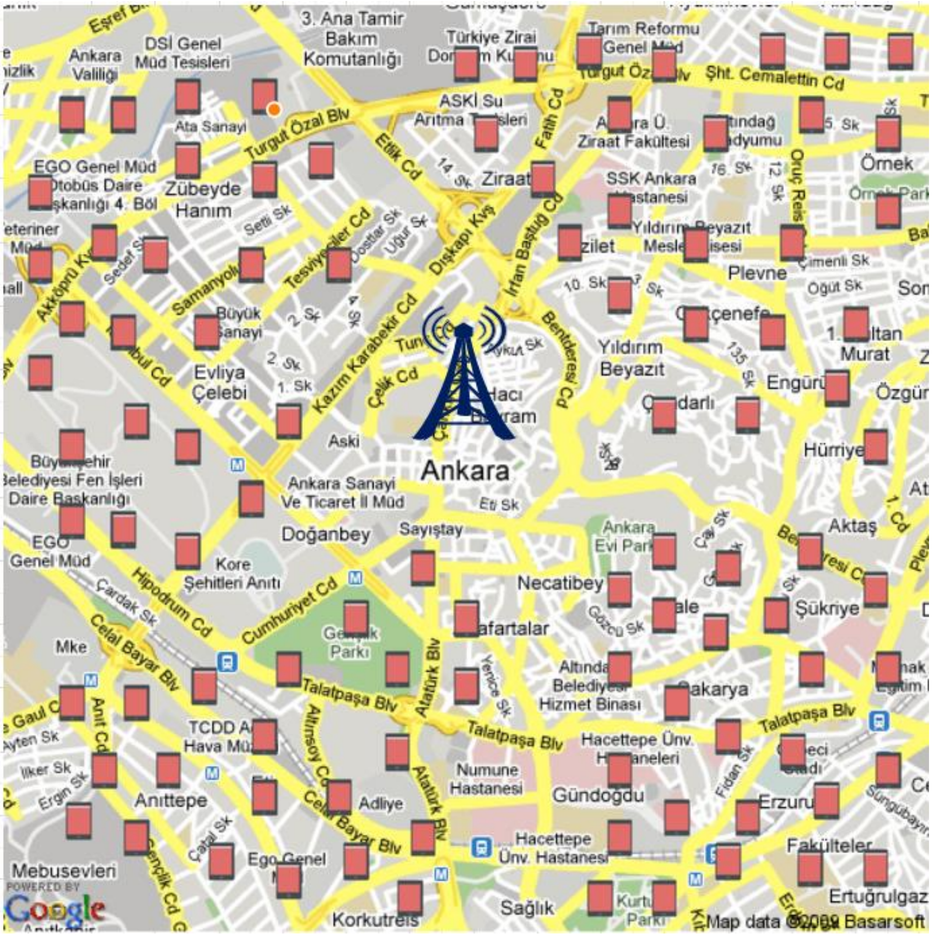

Figure 6.1. LTE network model [18]

6.3 ASSESSMENT OF THE SIMULATION RESULTS

We evaluated BET, MT, RR, PF, and TTA algorithms in an LTE system with 10, 20, 40, 60, and 100 Botnet. In Tab.6.2, all algorithms are illustrated using end-to-end average throughput data.

Table 6.2. Performance of Average Throughput values for MAC Scheduler

Performance of Average Throughput (Kbps)	MAC Scheduler				
	BET	MT	RR	PF	TTA
10 BotNet	4104.83	4540,95	4207,80	4601,47	4800,51
20 BotNet	2624,36	3074,30	2927,17	3218,04	3372,42
40 BotNet	1744,26	2409,08	2283,77	2427,57	2674,29
60 BotNet	511,46	941,57	933,17	1059,30	1202,96
100 BotNet	204,179	453,354	358,308	522,231	602,621

Figure 6.2 shows how TTA increased the number of botnets to get a greater throughput value than other algorithms. Because when performing the allocation procedure, the algorithm disregards the botnet's channel condition values. Although this average channel state over duration is low, PF throughput is less than TTA but better than others. Then it strives to provide a minimum quality of service to all users while maximizing total throughput in order to strike a balance between throughput and fairness for all users. The BET scheduler, on the other side, has the lowest throughput since it has typically allocated more resources to users with lower average throughput than users with higher average throughput. In comparison to other simulated schedulers, these results allow us to infer that the TTA scheduler provides the best throughput.

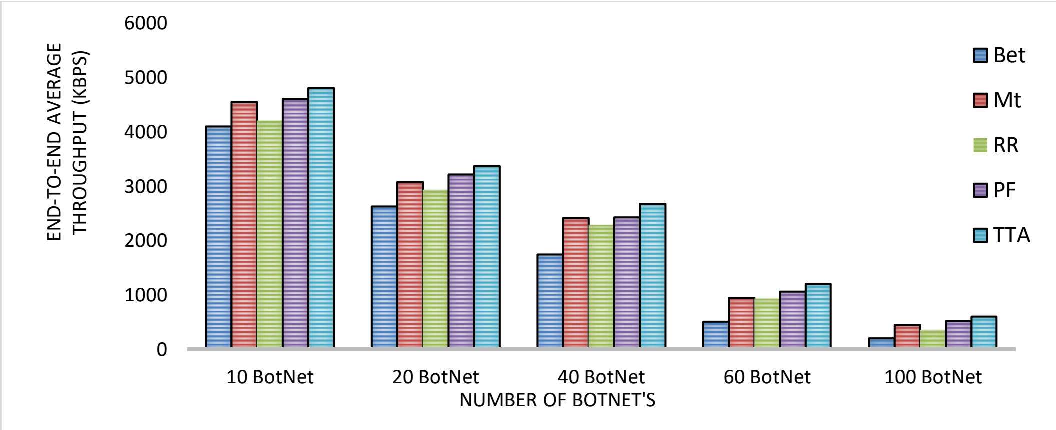

Figure 6.2. Average throughput values for MAC Scheduler

For users, the LTE network provides a smaller end-to-end delay, allowing them to access data in a short period. Table 6.3 shows that the average end-to-end delay increases as the number of botnets grows. End-to-end delays for Bet, Mt, RR, PF, and TTA methods occur late due to the sluggish processing time in the average packet mechanisms. In terms of metrics, the TTA algorithm lowers the delay. To put it another way, the more traffic the botnet is predicted to generate, the lower their metrics will be on a specific RB.

Table 6.3. Average end-to-end delay

Average Delay (ms)	MAC Scheduler				
	BET	MT	RR	PF	TTA
10 BotNet	123,02	119,56	118,00	112,32	106,65
20 BotNet	264,95	257,78	249,84	242,78	228,01
40 BotNet	565,02	466,57	452,21	439,44	412,70
60 BotNet	1007,12	992,12	907,62	898,66	816,24
100 BotNet	2712,63	2644,15	2481,14	2396,16	2245,76

Figure 6.3 shows that the TTA scheduler provides the lowest average traffic delays compared to the other schedulers because of its channel-unaware scheduling capability. As a result of real-time traffic can be transmitted in a short period of time. When the number of botnets exceeds 100 bots, the MT, TTA, and BET schedulers experience the most delay.

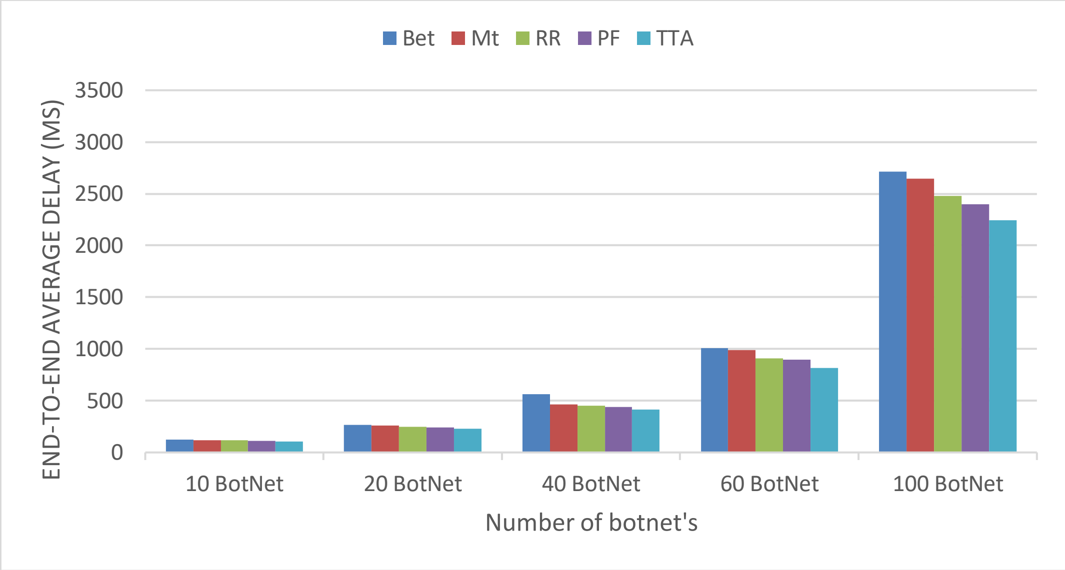

Figure 6.3. Average end-to-end delay

In Table 6.4, we can see how the PDF rate varies as the number of botnets rises. For evaluating network efficiency, the PDF, which is the ratio of the amount packets sent to full packets received, is critical.

Table 6.4.Average PDF rate %

Average PDF (%)	MAC Scheduler				
	BET	MT	RR	PF	TTA
10 BotNet	83%	85%	85%	87%	87%
20 BotNet	76%	79%	80%	82%	83%
40 BotNet	68%	70%	69%	71%	71%
60 BotNet	56%	58%	57%	64%	67%
100 BotNet	45%	50%	53%	54%	58%

Figure 6.4 indicates that when the number of botnets in the eNodeB network is low, the system's PDF is good because there are more resource blocks available compared to botnet data traffic. Since there are less resource blocks available in eNodeB as botnet data traffic grows, the network's PDF continuously decreases, due to a higher probability of packet loss from botnet queues at eNodeB. TTA algorithm outperforms other schedulers, according to the results.

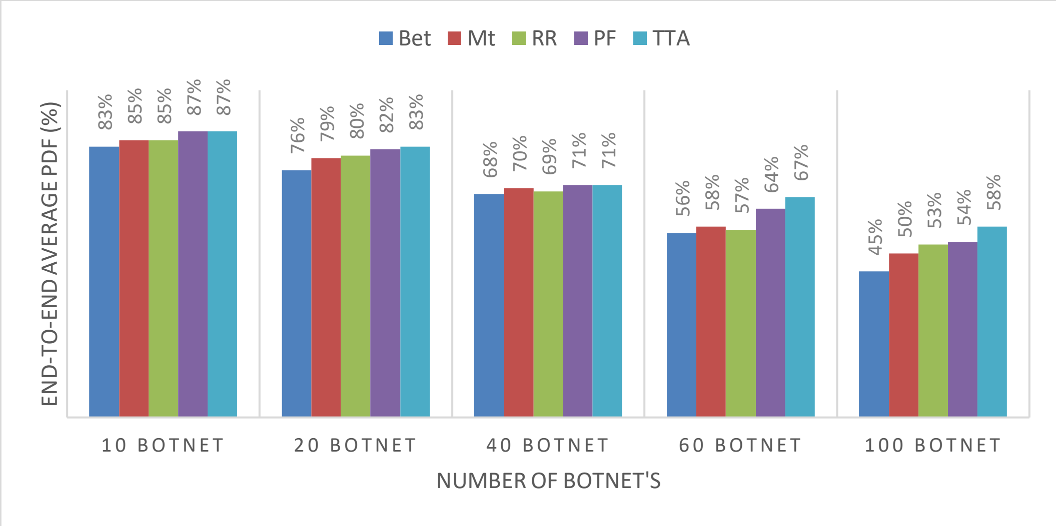

Figure 6.4. Average end-to-end PDF

All transmission protocols or peer-to-peer implementations in the LTE network interact effectively with packet congestion control techniques for the LTE system. Protocols must not take on more network resources than equivalent flows. Fairness index values for TTA, MT, PF, RR, and BET are shown in Tab. 6.5 in relation to the number of botnets using each of those methods.

Table 6.5. Fairness index

Fairness Index	MAC Scheduler				
	BET	MT	RR	PF	TTA
10 BotNet	0,91	0,92	0,90	0,96	0,97
20 BotNet	0,81	0,86	0,85	0,88	0,88
40 BotNet	0,71	0,73	0,73	0,75	0,79
60 BotNet	0,59	0,63	0,64	0,64	0,69
100 BotNet	0,38	0,42	0,47	0,47	0,53

The fairness index is a useful metric for assessing the efficiency of the scheduling algorithms. In this case, resources are shared among the botnets. The TTA scheduler achieves a significant fairness index value against the number of botnets, as seen in Figure 6.5. Because it handles the issue of fairness among users to deliver great outcomes without taking channel circumstances into account. MT and BET's unjust resource allocation is a result of duplicated allocation and resources starvation. The

RR algorithm, on the other hand, wastes a lot of resources because it prioritizes nodes close to the road side unit.

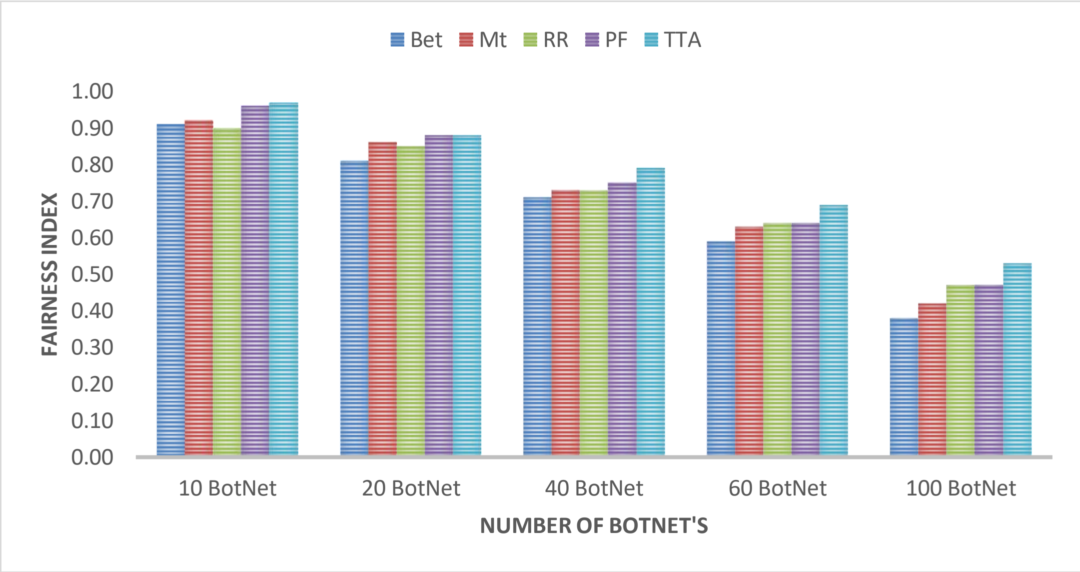

Figure 6.5. Fairness index

Simulated findings indicated that the TTA algorithm outperformed other algorithms such as MT, PF, RR, and BET in terms of throughput, delay, PDF and fairness.

PART 7

CONCLUSION

This study evaluates five scheduling algorithms (MT, TTA, BET, RR, PF) under DDoS using the NS-3 network simulation platform. The parameters for evaluating these algorithms include fairness, PDF, delay, and throughput. With the increase in the number of botnets attacking the LTE network, users cannot access network resources. With more occupation of the network, lower end-to-end media throughput, PDF and fairness index values are obtained. It also gives a higher end-to-end delay value. The simulation results show that the TTA algorithm has a suitable fairness attribute and is more efficient than other schedulers at reducing packet loss while achieving maximum throughput. For future works, improving the performance of the scheduling algorithms working in the 5G will contribute to increasing the system efficiency.

REFERENCES

1. Çakmak, M. and Albayrak, Z.,"Mobile Communication - Past, Present and Future: a Review", ***International Conference on Advanced Technologies, Computer Engineering and Science***, (2018).

2. Stüber, G. L., "Principles of Mobile Communication", Principles of Mobile Communication, 1–830 (2012).

3. Kuo, Y. F. and Yen, S. N., "Towards an understanding of the behavioral intention to use 3G mobile value-added services", ***Computers In Human Behavior***, 25 (1): 103–110 (2009).

4. Gómez, G., Pérez, Q., Lorca, J., and García, R., "Quality of service drivers in LTE and LTE-A networks", ***Wireless Personal Communications***, 75 (2): 1079–1097 (2014).

5. Lauridsen, M., Giménez, L. C., Rodriguez, I., Sørensen, T. B., and Mogensen, P., "From LTE to 5G for Connected Mobility", ***IEEE Communications Magazine***, 55 (3): 156–162 (2017).

6. Emmanuel, O., "Performance Evaluation of an Uplink Scheduling Algorithm in WiMAX Designing the Adaptive Heuristic Uplink Scheduling", (October): (2009).

7. Channagire, A. D. and Mane, A. D., "Performance analysis of long term evolution (LTE) medium access control (MAC) scheduler for real-time heterogeneous data traffic", ***2019 International Conference On Intelligent Computing And Control Systems, ICCS 2019***, (Iciccs): 1016–1023 (2019).

8. Marincic, A. and Simunic, D., "Performance evaluation of different scheduling algorithms in LTE systems", ***2016 39th International Convention On Information And Communication Technology, Electronics And Microelectronics, MIPRO 2016 - Proceedings***, 595–600 (2016).

9. Ismail, S. B., Ali, D. B. M., and Ya'acob, N., "Performance analysis of uplink scheduling algorithms in LTE networks", ***Indonesian Journal Of Electrical Engineering And Computer Science***, 9 (2): 373–379 (2018).

10. Sharma, A., Mahendra, V., and Kartik, S., "Performance analysis of MAC scheduling in femtocell for real time applications with QOS", ***Proceedings Of The International Conference On Computing Methodologies And Communication, ICCMC 2017***, 2018-Janua (Iccmc): 42–46 (2018).

11. Zhou, D., Song, W., Baldo, N., and Miozzo, M., "Evaluation of TCP performance with LTE downlink schedulers in a vehicular environment", ***2013 9th International Wireless Communications And Mobile Computing Conference, IWCMC 2013***, 1064–1069 (2013).

12. Raissi, K. and Gouissem, B. Ben, "LTE scheduler algorithms for VANET traffic in smart city", ***International Journal Of Computer Networks And Communications***, 12 (1): 53–64 (2020).

13. ALBAYRAK, Z., MUSA, H., and ÇAKMAK, M., "Performance Evaluation of WBANs MAC Protocols in Different dBm and OMNet++", ***Journal Of Intelligent Systems: Theory And Applications***, 4 (1): 1–7 (2021).

14. ÇAKMAK, M. and ALBAYRAK, Z., "LTE Ağlarda Remote-Host ile PG-W arasındaki Kuyruk Yönetim Algoritmalarının Performans Analizi", ***Academic Platform Journal Of Engineering And Science***, 456–463 (2020).

15. Zinno, S., Di Stasi, G., Avallone, S., and Ventre, G., "A Load Balancing Algorithm against DDoS attacks in beyond 3G wireless networks", ***2014 Euro Med Telco Conference - From Network Infrastructures To Network Fabric: Revolution At The Edges, EMTC 2014***, 1–6 (2014).

16. Ettiane, R., Chaoub, A., and Elkouch, R., "Robust detection of signaling DDoS threats for more secure machine type communications in next generation mobile networks", ***19th IEEE Mediterranean Eletrotechnical Conference, MELECON 2018 - Proceedings***, 62–67 (2018).

17. Shoket, H. and Aulakh, J. S., "Secure VOIP LTE network for secure transmission using PLRT (Packet Level Restraining Technique) under DDOS Attack", ***2018 5th International Conference On Signal Processing And Integrated Networks, SPIN 2018***, 878–882 (2018).

18. Çakmak, M., Albayrak, Z., and Torun, C., "Performance comparison of queue management algorithms in lte networks using NS-3 simulator", ***Tehnicki Vjesnik***, 28 (1): 135–142 (2021).

19. Albayrak, Z. and Çakmak, M., "A Review: Active Queue Management Algorithms in Mobile Communication", ***International Conference On Cyber Security And Computer Science***, (October 2018): 180–184 (2018).

20. Xu, R., Zhao, Z., and He, F., "DDoS attacks at MAC layer in tactical mobile ad hoc networks", ***Proceedings - 2010 International Conference On Communications And Intelligence Information Security, ICCIIS 2010***, 100–104 (2010).

21. Henrydoss, J. and Boult, T., "Critical security review and study of DDoS attacks on LTE mobile network", ***Proceedings, APWiMob 2014: IEEE Asia Pacific Conference On Wireless And Mobile 2014***, 194–200 (2014).

22. Engineering, E., "SECURITY CLASSIFICATION OF SMART DEVICES CONNECTED TO LTE NETWORK", 3–5 .

23. Ramesh, T. K., "A Survey on scheduling algorithm for downlink in LTE cellular network", ***Proceedings Of The 2nd International Conference On Smart***

Systems And Inventive Technology, ICSSIT 2019, (Icssit): 219–223 (2019).

24. Kukushkin, A., "Introduction to Mobile Network Engineering: GSM, 3G-WCDMA, LTE and the Road to 5G", 416 (2018).

25. Yi, S. J., Chun, S. D., Lee, Y. D., Park, S. J., and Jung, S. H., "Radio Protocols for LTE and LTE-Advanced", Radio Protocols for LTE and LTE-Advanced, (2012).

26. ALBAYRAK, Z. and Musa, H., "Kablosuz Vücut Alan Ağları için Enerji Verimli MAC Protokolleri (KVAA)", ***Academic Platform-Journal Of Engineering And Science***, (October): 127–113 (2017).

27. Zaki, Y., "Future Mobile Communications: LTE Optimization and Mobile Network Virtualization", Future Mobile Communications: LTE Optimization and Mobile Network Virtualization, 1–173 (2013).

28. Subramanian, R., Ghosal, P., Barua, S., Xing, S., Cong, S., Al Kim, H., and Sandrasegaran, K., "Survey of LTE Downlink Schedulers Algorithms in Open Access Simulation Tools NS-3 and LTE-SIM", ***International Journal Of Wireless & Mobile Networks***, 7 (2): 01–16 (2015).

29. Altunay, H. C., Albayrak, Z., Ozalp, A. N., and Cakmak, M., "Analysis of Anomaly Detection Approaches Performed through Deep Learning Methods in SCADA Systems", ***HORA 2021 - 3rd International Congress On Human-Computer Interaction, Optimization And Robotic Applications, Proceedings***, (July): (2021).

30. Azahari Mohd Yusof, M., Hani Mohd Ali, F., and Yusof Darus, M., "Detection and Defense Algorithms of Different Types of DDoS Attacks", ***International Journal Of Engineering And Technology***, 9 (5): 410–444 (2018).

31. Kabir, M., Islam, S., Hossain, M., and Hossain, S., "Detail comparison of network simulators", ***International Journal Of Scientific & Engineering Research***, 5 (10): 203–218 (2014).

32. Mishra, V. and Jangale, S., "Analysis and Comparison of different wireless network simulators", ***International Technological Conference-2014 (I-TechCON)***, 4: 65–68 (2014).

33. Thapar, V., "A Comparative Study of Cloud Simulation Tools", ***International Journal On Computer Science And Engineering (IJCSE)***, 9 (06): 385–392 (2017).

34. Zhou, X. and Tian, H., "Comparison on network simulation techniques", ***Parallel And Distributed Computing, Applications And Technologies, PDCAT Proceedings***, 0: 313–316 (2016).

35. Lessmann, J., Janacik, P., Lachev, L., and Orfanus, D., "Comparative study of

wireless network simulators", ***Proceedings - 7th International Conference On Networking, ICN 2008***, 517–523 (2008).

36. Uwuburiza, A. H., "Comparative Study on Performance of NS2 versus OPNET Network Simulators on Large Scale Network", 9 (11): 9–13 (2019).

37. Khan, R., Bilal, S. M., and Othman, M., "A Performance Comparison of Network Simulators for Wireless Networks", ***A Performance Comparison Of Network Simulators For Wireless Networks***, 1–6 (2013).

38. ALBAYRAK, Z. and Musa, H., "Energy Efficient MAC Protocols for Wireless Body Area Networks", ***4th International Symposium on Innovative Technologies in Engineering and Science (ISITES2016)***, 3-5 November (2016).

RESUME

Samatar MOHAMED ALI graduated from first and elementary education in Djibouti. He completed his high school education at Gabode High School, and then, he obtained a bachelor's degree from the University of Djibouti in Mathematics and Computer Science Department of Sciences in 2018. He studied Turkish Language in Cankiri, Turkey, from 2018 to 2019.To complete his M.Sc. education, he moved to Karabuk/Turkey in 2019. He started his master's education at the department of computer engineering at Karabuk University.