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EDITOR'S NOTE TO CONTRIBUTORS AND READERS

Journal of Communication Technology and Business continues its goal of trying to publish quality articles submitted for consideration. We continue to underscore our commitment to intellectual engagement and academic discourse and intend to ensure and maintain continuity in our interrogation of issues relating to African's Technological advancement, Communication and Business. We are excited by the challenge of serving you and are gratified by the increasing level of interest in the journal. We feel it is critical that the journal continues to remain truly interdisciplinary, though not every article submitted need to be interdisciplinary in orientation. We are mindful though that most of our volumes may be dominated by papers from technology, communication, and business experts. We are interested in papers by junior scholars, senior scholars and graduate students as well. In short, we are looking for polished and "uncut diamonds" because we want to provide a platform for people to disseminate the results of their research. The present volume of Journal of Communication Technology and Business like the previous one, covers a very broad range of topics. Given the politics of the academy, we have taken the extraordinary step of publishing this volume, at considerable expense to the journal and the people who work on it, with an academic printing press in the glorious capital of Ghana. We wish to thank the members of the Editorial Board and the Editorial Advisory and Review Board for working assiduously on this volume. It is, indeed, a labour of love. Above all, we thank all the contributors to this volume, those who have contributed to the next volume (a remarkable effort indeed) and those who are looking forward to making contributions in the future.

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The Editorial Board welcomes manuscripts, which should be in the English language, and must be typed, double-spaced (including footnotes, endnotes and bibliography) using Times New Roman Font size 12. Manuscripts must not exceed 25 pages (or 6,250 words) and should be in Chicago Manual Style (16th Edition) or APA Referencing and Citation Styles (6th Edition). All submissions must be accompanied by a statement that the manuscript has not been previously published or submitted for publication elsewhere. The Editorial Board also welcomes newly published books from authors and publishers for review. Electronic submissions are to be made in Microsoft Word format, with the file name clearly indicated.

Each manuscript should be accompanied by an abstract of not more than 150 words. All works consulted should be listed serially at the end of each article under the headline BIBLIOGRAPHY. Manuscripts must also be accompanied by a separate (cover) sheet indicating the title of the paper, the author's name in the form it should appear in print, current academic or professional position, field of interest, institutional affiliation and address of the author(s). For the purposes of blind peer-review, the first page of the manuscript should not bear the name(s) of the author(s).

All manuscripts and enquiries should be sent to: The Editor, Journal of Communication Technology and Business of the Directorate of Research Innovation and Consultancy, Ghana Communication Technology University, Ghana or via email to:

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ARTICLE 1

ABSTRACT

Workplace peace is an essential tool for the survival of every company and employee as such. The existence of peace creates an atmosphere conducive for hardwork, good teamwork and interpersonal relationship that grows to support an organizations core mandate. So that in the absence of peace, the employee faces an unfavorable organizational climate which in turn will lead to low productivity or cause them to leave the organization entirely. Based on the above, this paper proposes a conceptual framework that seeks to establish a link between workplace peace, effective communication, organizational climate and employee turnover. The conceptual paper proposes that there exists a relationship between workplace peace and organizational climate and also, workplace peace and employee turnover. There is also a relationship between workplace effective communication and organizational climate as well as workplace effective communication and employee turnover. Once a company loses out on any of the elements in the model, employee turn over rate is going to increase to the detriment of the firm.

Proposed methodology: This paper employed an in-depth literature review using Papers on workplace peace, organizational climate, workplace effective communication, and employee turnover in general. Only Scopus indexed journal articles were used.

Implications: It is hoped that, this proposed conceptual framework will draw managements attention to the need to ensure that peace exists in every organization and foster a conducive atmosphere, whereby the most significant responsibilities can be performed efficiently. It is also expected that managers take effective communication seriously since its effects are dire to every organization. Lastly, it is expected that every individual understands this nexus for their efficient survival in every organization.

Keywords: Workplace peace, effective communication, organizational climate, employee turnover

THE NEXUS BETWEEN WORKPLACE PEACE WITH EFFECTIVE COMMUNICATION AND EMPLOYEE TURNOVER: A CONCEPTUAL FRAMEWORK

1.0 INTRODUCTION

Employees devote a huge percentage of their periods at the workplace, therefore, the value of the working atmosphere creates a substantial effect on the welfare of employees. To construct a productive organization also involves developing a diplomatic, collective and supportive work atmosphere for all the employees and the organization as a whole. The workplace is kind of a unique place in some ways because, the individuals we interrelate with are not selected by us most often and therefore, connecting to them is not equivalent to relating to family and friends. Nevertheless, professionals advocate that, it is the duty of businesses to endeavor to categorize themselves with a nonviolence or nonaggressive culture where the fundamental human standards of sympathy, understanding, belief, love, shared respect and compassion are implanted.

This is however not the case most of the time. Hunte (2016) states the plight of Black tradeswomen for example, where incidents of racism, sexism, and heterosexism happen throughout their careers, and varied in intensity and personal impact. Such conditions as patriarchy, white dominance, and competition within their unions and institutions; minimal responses of human resources and contractors to acts of discrimination, insensitive behavior, bullying and the like prevents the existence of a free workplace that truly values everyone. At different points in their careers this impacts their abilities to find work, retain work, and/or attain promotion.

Dawa (2007) further states that “Learning to live together” involves creating new space and process to learn techniques to manage, negotiate, resolve, and prevent the different conflicts that

emerge in our lives, such as peer mediation, anger management, active listening, stress reduction, meditation,values clarification, self-esteem, and team building. Thus conflict management should be key to every organization and should be done in good time to avoid destructon. There is evidence that workplace hostility causes people to leave the workplace. What this means is that, if workplace peace and the organizational climate as a whole is nonexistent, it will easily lead to decreased work and a complete employee turnover. Therefore for employees to work together and increase their output, businesses need to maintain a conducive culture.

Again, in Basabose's (2017) work on peace building in Rwanda, he states that corruption has increasingly undermined peacebuilding processes, therefore anticorruption efforts are needed as one of the ways of building and sustaining positive peace. Some approaches he therefore suggests are developing legal and punitive frameworks to act as a deterrent to others, devising bureaucratic structures that make its practice more difficult, and promoting ethical value-based approaches. Similarly, a good work environment in which there exists effective communication and ultimately peace can be said to be the process for ensuring success in every organization and a productive workforce.

Scholars have also tried to study the positive link between employees in general and their work output. Lorenzo (2000) describes a democratic workplace as a community, with a gathering of workers who share values beyond the corporate values of efficiency and productivity. These communal values include priority of labor over capital, solidarity, equitable distribution of earnings, democratic management, balance between the workers' welfare and the corporation's profitability, and continuing education.. Workplace democracy has been envisioned as essential for a truly democratic and egalitarian society. Democratic socialists have long held that full and effective participation of workers in the decisions made in their workplaces is indispensable for

overcoming alienation, encouraging participatory democracy and promoting radical social change (Smith 2000). Thus an organization that ensures consultations with and among the various levels of staff, are sure to have the benefits of effective communication. Such broad consultations augur well for peace to reign in the workplace thereby leading to a company's achievement of set goals. It is in the context of the above, that this paper seeks to propose a conceptual framework that establishes a link between workplace peace, workplace effective communication, organizational climate and employee turnover. It holds that there exists a positive relationship among all the four propositions so managers need to pay attention to each, if their organization's objectives are to be met.

2.0 WORKPLACE PEACE

The perception of administrative peace is an energetic condition that can progress using open communication, whose key fundamentals are fairness, belief and kindness and distresses the peace as well as the happiness of people (Yurdagul, 2019). Peace is an idea of social friendship, bond and harmony in the non-existence of aggression and violence. It can as well be explained as the non-existence of conflict or struggle. Work connects individuals of diverse personalities, charisma and comportment and this frequently results in friction, bitterness and anxiety (Remez, 2022). Maintaining peace at the workplace is attainable via increasing one's alertness towards the level where peace remains something he or she values and protects and wish to groom (Deepak, 2016). In a working environment where there is an absence of peace, there is a weakening of physical and psychological well-being of staffs (Duan et al., 2019), decreased confidence and inspiration of personnel (Berlanda et al., 2019), endangered, uncomfortable, disgraced or ashamed employees

(Viglianti et al., 2018) and also nonattendance and turnover (Sun et al., 2017). Conflicts at the workplace may be influenced via reasons such as;

- Distrust or doubt.
- Unsatisfactory management.
- The absence of communication, either among co-workers or among management and employees.
- The failure to share an idea or a misinterpretation of what the organization's goals or main concentration is.

In this extremely aggressive and ambitious time, there is the need for organizations to understand that, its tactical goal can be achieved basically through human resources (Chakraborty & Biswas, 2019). Meaning, industrial associations should be meticulously attended to with a non-mechanistic method.

3.0 WORKPLACE EFFECTIVE COMMUNICATION

From ancient time, communication has remained the utmost significant actions of human lives. Communication makes it probable for interactions to take place between people and employees of an organization (George & Alexandru, 2017). Communication is a very critical and substantial component in an organization and it is an essential item, meant to create teamwork inside the work setting that has effects on administrative presentations and decision making. As modest as communication might appear, research has revealed that, communication can shape or terminate a company's survival. Communication has generally remained recognized by numerous persons as the lifeblood of an organization for the reason being that, it is essential and required for circulating

information between staff, bartering of thoughts, creating effective policies and suggestions, entering into contracts, implementing decisions, conveying and completing commands and steering sales. Through communication, business events proceed appropriately.

Communication may be well-defined as the totality of entirely the things an individual does when he or she desires to generate consideration in the mind of another person. It comprises of an organized and constant procedure of telling, hearing and understanding. It is a critical instrument of societal relations and a channel through which all associations are recognized and sustained. In the business field, absolutely nothing can be attained in the absence of effective communication with bosses, staff, customers, suppliers and clients (Shonubi & Akintaro, 2016). Workplace communication is important to an organization's capacity to be industrious and function effortlessly.

Communication performs two indispensable purposes in every organization. That is;

- ✓ It circulates the information required by staff to perform their duties.
- ✓ It shapes relations of trust and commitment. Communication performance can have a substantial influence on the value of relations established inside the organization (Sharon & Natassia, 2019).

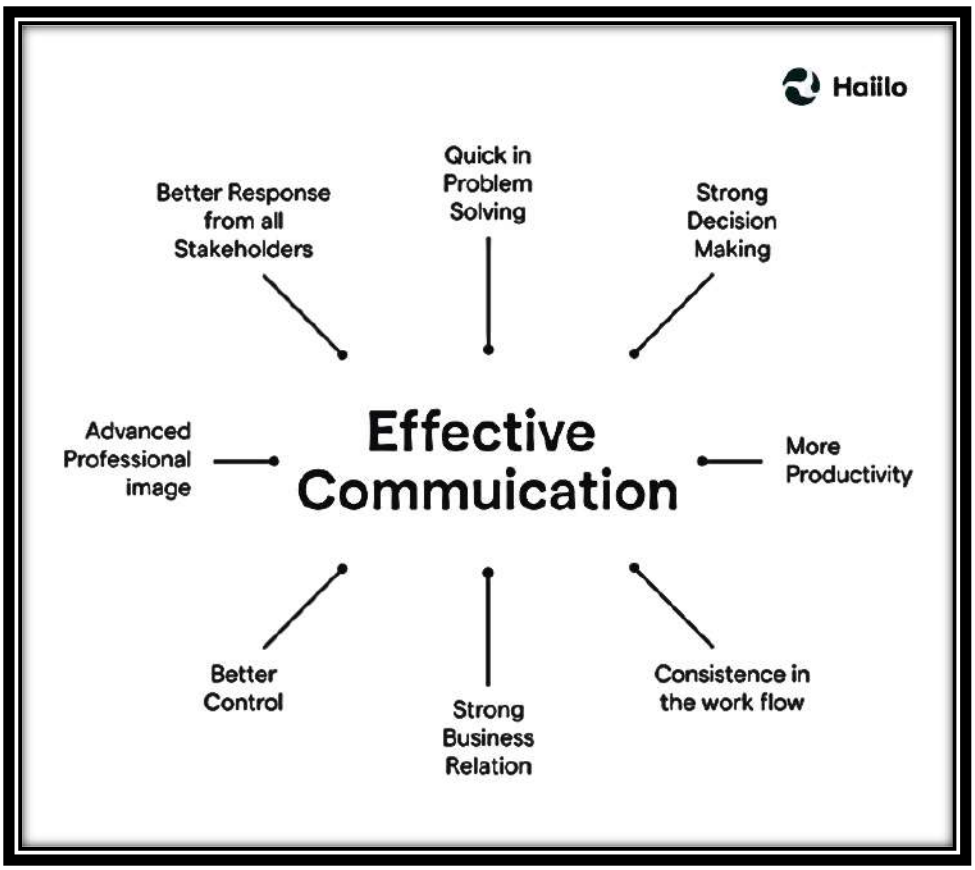
Effective communication entails skills and also, their growth entails training (George & Alexandru, 2017). Executing effective communication skills, tools and policies in the workplace is important for organizations to enhance productivity and remain competitive. In every human organization, the art of communication cannot be overstressed. It is the way by which individuals interrelate and work with each other. Similarly like the circulation of blood in humans, communication signifies the bloodstream of an organization. This means that, nothing can be

accomplished in a business without effective communication (Shonubi & Akintaro, 2016). Ineffective communication in an institution might end up in ambiguity, anxiety and discontent which will also result in poor productivity. Therefore, it is essential that supervisors communicate with workers effectively. The degree to which a director achieves business goals rests on his capacity to communicate effectively (Lovlyn, 2016).

Importance of effective communication at the workplace

Communication concerns structuring relationships, curtailing errors and mistakes and most significantly, working as efficiently as possible. A reliable communication can improve cooperation and lead to improve project partnership. Workplace communication is significant for restructuring internal communication. Sustaining effective communication guarantees that, management and the crew underneath them are of the equal view (Andy Cheng, 2022). Hence, good communication is an indispensable instrument in attaining productivity and preserving solid working relations at every stage of an organization.

Below is a conceptual framework of the importance of an effective communication system;



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4.0 ORGANIZATIONAL CLIMATE

Considering the way climate is in an organization contributes meaningfully to retaining talents and gifts and minimizing absenteeism. Organizational climate is an image of the perceptions that a member of staff has concerning his or her work setting. Organizational climate is otherwise known to be corporate climate as it measures the values of an organization. It also has a substantial effect on job fulfillment, productivity and motivational stages of the workforce in the organization (Hitesh, 2020).

Organizational climate can be defined as the component of a proficient atmosphere that contains a solid impact on the acts and performance of the staffs working in that company. It specifies

whether the prospects and opinions of the people are rewarded (Hitesh, 2020). Steinke et al. (2015) maintain their stand that, organizational climates mirrors workers' perceptions of the procedures, performances and dealings that are projected, reinforced and satisfied in respect to the human resources of the business. Also, Abbas et. al (2021) labelled organizational climate as a tiresome model of comportment, attitude and sentiments which classifies the usual routine in the workplace and are often related to organizational culture, values and standards.

Numerous businesses overlook organizational climate and so, employees' work activities and efficiency may be very minimal. Organizational climate specifically explains the manner in which people in an organization perceive and describe their work setting in an attitudinal and value-based style. Perceptions might for instance, comprise concepts of collaboration, management support, trust, equality, openness, struggles, performance ethics and obligation (e.g., Cygler et al., 2018). Hence, irrespective of the magnitude of an association, it is significant that the association develops an outstanding bond with its workers. For instance, as stated by Hamidianpour et al. (2015), organizational climate has a constructive and a substantial power on employee's inventiveness in small and medium-sized organizations.

Types of organizational climate

The following are the common types of organizational climate;

- ***People-oriented Climate***

The people-oriented climate is an organizational philosophy, that has a fundamental set of standards, that concentrates mainly on caring for its workforce and their outputs.

- ***Rule-oriented Climate***

The rule-oriented climate is an organizational philosophy, that provides a set of guidelines and structure and puts high significance on following these guidelines and consideration to detail from everyone.

- ***Innovation-oriented Climate***

The innovation-oriented climate is an organizational philosophy that constantly progresses and announces innovative habits of working and procedures (and inspires personnel to do similar) to accomplish innovative outcomes.

- ***Goal-oriented Climate***

The goal-oriented climate is an organizational philosophy that puts importance on morals and filtering specifics of procedures to attain the anticipated outcome (Shani, 2020).

Factors affecting organizational climate

- Physical space features and staff security
- Dealing with supportive persons.
- The level of struggle and lenience the work atmosphere can bear.
- Management styles and policymaking procedure
- Working with a knowledgeable leader.
- The structure of the organization as well as instructions, rules and restrictions.
- Roles, purposes, goals and task in the organizational setting (Hitesh, 2020).

Organizational climate influences employee performance by;

- Providing an atmosphere where staffs either feel content (satisfied) or displeased (dissatisfied). A satisfied employee is one who is being motivated by an excellent and positive work environment and that also boosts his or her level of performance. Therefore, an unsatisfied employee is one who is not being motivated by the work environment that he or she finds his or herself.
- Having a substantial impression on the attitude of staffs.
- Providing a reliable or unreliable organizational climate which improves or troubles the efficiency of an employee (Hitesh, 2020).

5.0 EMPLOYEE TURNOVER

How magnificently an organization recruits, onboards, accomplishes and rewards its employees is essential to victory. According to Marc (2021), turnover calculates departures of staff from the organization (i.e., staffs who exit an organization during a particular period, irrespective of the motive). Employee turnover discusses the sum or proportion of employees who exist an organization and are substituted by new staffs. Turnover frequently happens due to the demise, retirement, infirmity or the will of employees. Employee turnover destructively influences the association by increasing employment expenses, consuming recruiters' time and depressing other staff. The corporation's losses due to employee turnover remain enormous (Maryna, 2021).

Types of employee turnover

- ***Voluntary Turnover***

This type of turnover explains that, individuals depart from the organization, based on their personal decisions. This is when a staff chooses to willingly exit the organization. It is the staff's decision to separate away from the organization, without a burden from any external force. With the voluntary turnover, employees often leave to pursue additional money and time off, increased profits, career development, an extra ideal work or life balance, an upgrade, to chase educational prospects or to escape an unsuccessful or toxic superior or for individual motives.

- ***Involuntary Turnover***

Involuntary turnover is when an employee is sacked or required to exit the organization due to numerous reasons. This is where an employee has been terminated or was among a recurrent redundancy or decrease in force. They could also be employees who fail to meet performance standards and work prospects or have misbehaved (Marc, 2021).

- ***Desirable Turnover***

A turnover is measured desirable once an organization exits or misses underperforming staff and substitutes them with new employees. This procedure might not be accepted by majority of workers, but it is important to preserve the energy going within the organization.

- ***Undesirable Turnover***

An undesirable turnover is when an organization loses its topmost performing staffs. Some staffs leave behind a profound impression than other staffs. Those are the workers that are difficult to be substituted.

Methods to reduce employee turnover in a workplace includes;

- Appointing the precise individuals from the beginning.

- Generating a sufficient workplace.
- Creating the appropriate compensation and benefits.
- Showing courtesy to staffs' individual requests and offering additional flexibility.
- Appreciating or applauding after a project.
- Revising compensation as well as benefits packages (at least, yearly). The reason being that, high earnings are precisely what employees need the most to accomplish their basic physiological desires.
- Making sure brilliant employees feel they are performing a befitting substantial role in attaining the organizational goals.

Based on the above, we make the following propositions:

P1 – There is a positive and significant relationship between workplace peace and organizational climate

A. WORKPLACE PEACE AND ORGANIZATIONAL CLIMATE

Conflicts in an organization might appear like an irritation, but its consequences can destabilize the organization's culture and influence the organization's bottom line straight away. Peace and harmony have constantly remained among the maximum standards of humankind. In any business organization, an environment of peace and harmony is a pre-requisite for the accomplishment of established goals and objectives.

Organization climate is a characteristic that influences the functionality of a business. It affects staff conduct in every organization. The climate of an organization is bound to change often and can be designed by the superior administration of an organization. Climate is the organization's

mood or temperament. Organizational climate is the easiest to experience and quantify and similarly much easier to modify (John, 2021).

Organizational climate denotes an employee's lifelong perception of the working atmosphere and culture of the organization they work for. Climate is comparable to human character. Therefore, every individual has an exceptional character and so, every organization has an exclusive climate, which is a set of characteristics and features perceived by employees. These inspires employees conduct at the workplace across numerous magnitudes such as relationships, independence and organizational structure.

Therefore, if there is no peace in an organization, employees will experience an unfavorable organizational climate which in turn will cause employees to underperform. Therefore, there is a positive and significant relationship between workplace peace and organizational climate.

P2 – There is a positive and significant relationship between workplace peace and employee turnover

B. WORKPLACE PEACE AND EMPLOYEE TURNOVER

Peace commences with devoting one's self to being part of the result instead of being part of the problem (Deepak, 2016). Sustaining harmony in the workplace must be the main concentration of every business. Conflicts in the organization can end up with manners such as intimidation, pestering and discrimination. Employees can lack inspiration, fail to perform as a team and be generally unhappy or sad. The achievement of every organization seriously relies on its employees and it is critical to preserve high confidence between them, so that every staff has the ambition to complete his or her responsibilities and to meet the everyday quota. Nevertheless, a tensed and

disorganized organization can swiftly breakdown their spirit and minimize productivity, disturbing the outcomes of the entire organization at the same time.

Employee turnover is a serious subject challenged by various businesses globally. Not only is turnover expensive in relations to employing and training of new staff but, it can similarly be expensive in relations to decrease in earnings through condensed team performance and service levels (Yuko et. al., 2020). Since the achievements of an organization rests on the shoulders of its employees, if there is a risk of any quitting intent of staff, then, the association will have a long-term consequence of this huge encounter (Syeda et. al., 2018).

Therefore, if there is no existence of peace in an organization, employees will be unsatisfied, which in turn will cause employees to take drastic decisions such as leaving the organization. Therefore, there is a positive and significant relationship between workplace peace and employee turnover.

P3 – There is a positive and significant relationship between workplace effective communication and organizational climate

C. WORKPLACE EFFECTIVE COMMUNICATION AND ORGANIZATIONAL CLIMATE

There is a direct connection between communication and the degree to which staff enter an organization, as well as their intension to exit an organization. Good communication is important in every aspect of life, but specifically in an organization. Communication makes it likely to create connections among members of the organization (George & Alexandru, 2017). It is only through communication that people begin to appreciate, learn to admire respectively, build faith and

determine them and how individuals are perceived. Hence, persons who communicate efficiently, recognize in what manner to interrelate submissively, competently and reliably (Mihaela, 2021).

Organizational climate controls the working atmosphere in which the employee feels content or displeased. Since fulfillment regulates or inspires the effectiveness of staff, then it can be said that, organizational climate is directly linked to the productivity and performance of staff. Organizational climate demonstrates the attitudinal characteristic, opinions, sentiments and mainly the mood of workers at a specific time (Mihaela, 2021).

All businesses continuously attempt to improve staff performances. For this cause, leaders are required to discover ideas and solutions to produce employee eagerness which is crucial since, eagerness at the workplace echoes a profound desire in the direction of the work that is executed so that, work can be achieved quicker and better outcomes can be attained (Andi, 2019). Hence, communicating ineffectively distorts work, destroys trust, creates chaos and so on. Therefore, this creates a discomfort for employees and the atmosphere becomes unfavorable for them as they perform their duties. So, to conclude, we can say, there is a positive and significant relationship between workplace effective communication and organizational climate.

P4 – There is a positive and significant relationship between ineffective workplace communication and employee turnover

D. INEFFECTIVE WORKPLACE COMMUNICATION AND EMPLOYEE TURNOVER

Good communication practices remain at the heart of each successful organization. Communication is the method of distributing ideas, information and messages with others at a specific period and place. Communication comprises of writing and speaking, alongside,

nonverbal communication (for instance, facial expressions, mannerisms, or even signs), visual communication (i.e., the usage of images such as, painting, photography, video or film) and electronic communication (for instance, telephone calls, automated mail, cable television or satellite transmissions).

Communication is measured as an important instrument for administrative performances and development. This is because, most industries depend on effective communication together with clients and staff to advance sales and improve business growth. On the other hand, poor or ineffective communication usually ends at mishandling of an association and unwanted business outcomes (Stavros, 2020).

Most scholars have come to an agreement that, the intention of a staff to remain or exit an organization is the last reasoning step in the voluntary turnover procedure. This is because, for an employee to take the decision of exiting an organization, then that will mean, the level of satisfaction expected has either not been met or below average. The decision to stop working for an organization is the intellectual response of a person to clear organizational situations that collapse a range of events of organizational extraction from gazing into space to the corporal act of resigning (Mahfuzur & Valliappan. 2020).

As it is stated earlier that, poor or ineffective communication usually ends up at mishandling of a business and unwanted corporate outcomes, employees will consequently, take the decision to leave, because, no employee enjoys working in an organization where mismanagement and less productivity is the culture. Therefore, if employees are getting these feedbacks, then they will definitely take the decision to leave to a better place. Hence, there is a positive and significant relationship between an ineffective communication and employee turnover.

P5 – There is a positive and significant relationship between organizational climate and employee turnover

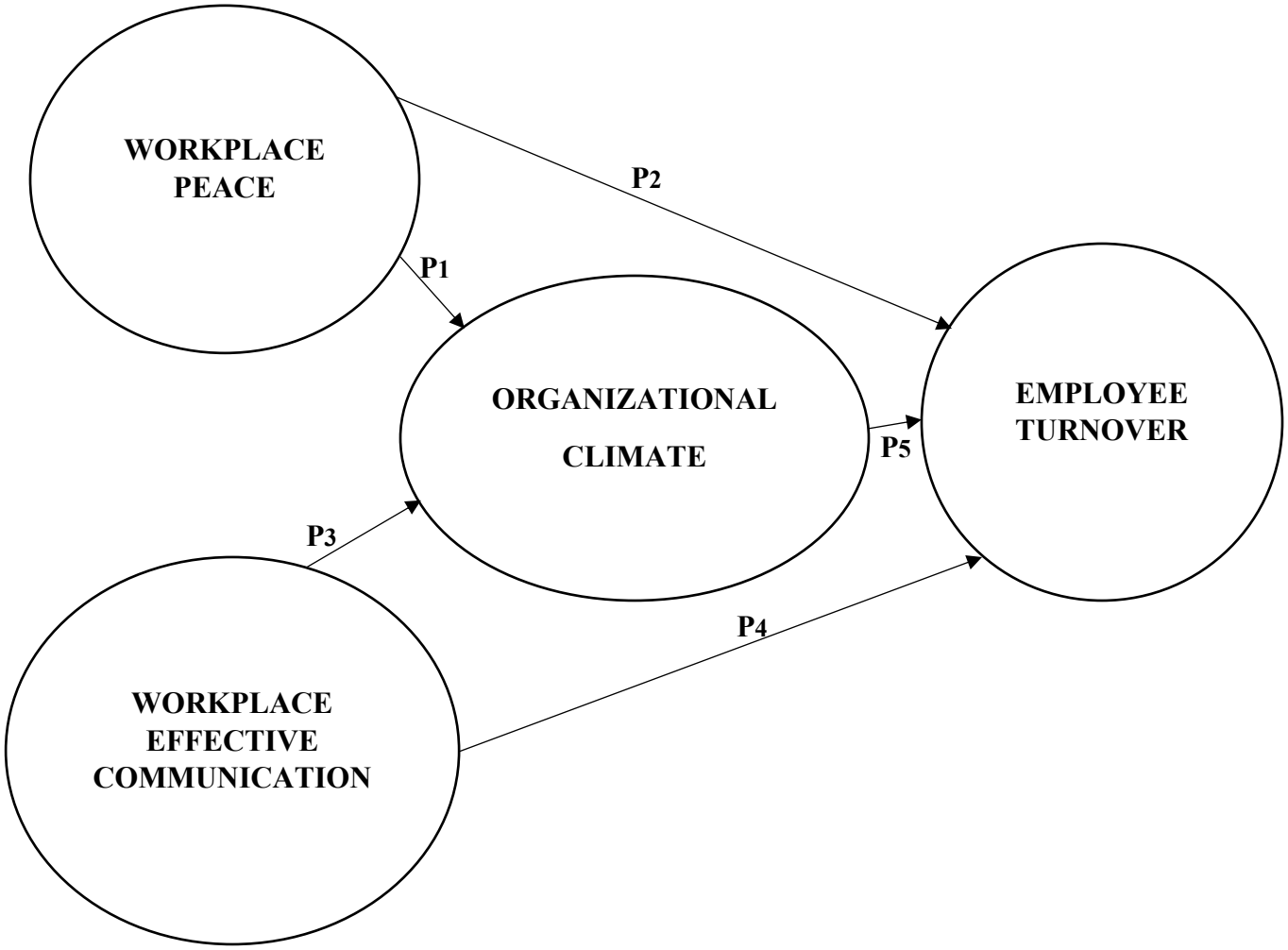
E. ORGANIZATIONAL CLIMATE AND EMPLOYEE TURNOVER

Climate is not formed instantly, but rather, it is constructed and designed over an extended period of time, through a collection of practices and connections. A constructive organizational climate intensifies organizational obligations, that is, it generates a tie between staff and their organizations. It is associated with the value and the appropriateness of the work atmosphere. It is concerned with the support that staff feel they obtain from the business. Organizational structure sturdily impacts organizational climate. The organizational climate is an image of the degree of staff motivation. It is about how workers feel once they are at the workplace, which has a direct relationship with how motivated they are to perform well. Staff who are left to find out personally, will be less inspired in their state of confusion, which will lead to disengagement.

Employee turnover rate also has a significance on the organization's operational expenses and decreases the organization's social wealth. The higher the turnover rate, the larger the costs for the organization will be. Such a situation will end up in higher investments in human resources, specifically, high investment charges for staff development which will affect production costs.

Therefore, if the organizational climate of an institution is satisfactory, employees are motivated and they work effectively to achieve the common goal of the institution but if the organizational climate of an institution is unsatisfactory, then there will be employee turnover. Therefore, there is a positive and significant relationship between organizational climate and employee turnover.

A CONCEPTUAL FRAME WORK



From the diagram above:

- There is a relationship between workplace peace and organizational climate and also, workplace peace and employee turnover.
- There is also a relationship between workplace ineffective communication and organizational climate as well as workplace ineffective communication and employee turnover.
- Also, there is a relationship between organizational climate and employee turnover.

6.0 DISCUSSION OF THE PROPOSED CONCEPTUAL MODEL

From the proposed conceptual model given above, it can be said that there exists a strong interdependence between workplace peace, organizational climate, and turnover, and ineffective communication that may ultimately lead to a high employee turnover.

Workplace peace and organizational climate measures the extent to which an organization's climate fosters the peace of employees to enable them give off their best towards the achievement of set goals and objectives. Hence the model holds that if an organization's climate is sour, it negatively affects its employees and vice versa. Without the employee having peace and harmony within an organization, standards set in terms of achieving excellence cannot be met, and this will in turn lead to dissatisfaction and disappointments in the employee and ultimately play to his willingness to quit the job. The organizational climate therefore remains central to the success or failure of the individual and by extension, the company. Therefore, if there is no peace in an organization, employees will experience an unfavorable organizational climate which in turn will cause employees to underperform..

Furthermore, the organizational climate also has a positive correlation to high employee turnover, in that , the loss of interest in ones job leads to a failure on ones part to put in any effort towards the success of the company. Their ambition to make the company succeed is dwindled most often in such a tense environment, this affects the company as a whole whilst also leaving the employees with no option than to leave. This results in apathy which at the end of the day affects an organization's growth and ultimately the loss of staff.

Central to an organisations climate and employee turnover is also the lack of effective communication. If staff are unable to voice out their grievances with the hope that they will be given an ear, they end up bottling issues inside them which later may lead to workplace unrest and ultimately leaving the job. In an organization where the climate does not foster effective communication at all levels, work is distorted, there exists no trust, and people bear unnecessary grievances. There is therefore discomfort for employees and the atmosphere becomes unfavorable for them to perform their duties. The end result is employees leaving an organization in search for a work environment that allows effective communication.

6.1 MANAGERIAL IMPLICATIONS

Maintaining workplace peace and harmony in an organization is a challenge facing every manager due to the broad definition of the term peace. What managers should do is to ensure that, the existence of an ideal climate in the workplace to guarantee the peace that is needed by employees to meet their organizational goals exists at all times. Sustaining harmony in the workplace and preserving optimum confidence in employees must be the main concentration of every manager in order to achieve his company's goals and targets. In the absence of this, employees who work in a tensed and disorganized firm can easily get their spirits broken down leading to minimized productivity, disturbing the outcomes of the entire organization at the same time.

The degree of uncertainty in human behaviour as a result of both the internal and external factors of peace makes it entirely difficult to predict employees and especially, employee turnover at any point in time. To minimize this problem, managers must always brace themselves with periodic stakeholder engagements to discuss issues and as much as possible come out with policies and strategies to solve them amicably. This will motivate staff to give off their best in order for the company to attain maximum profitability. Additionally, a high turnover has financial implications on managers and their companies as a whole due to the fact that earnings from the work of productive staff is lost and the cost of hiring and training of new staff to do the job becomes high. Managers should therefore do their best to prevent this occurrence else their companies turn to

lose on a large scale with long term consequences. This conceptual model also begs management in organizations to keep the communication lines between employees and management open at all times. The chain of reporting should not be bureaucratic in nature so that aggrieved employees can have their issues heard and addressed. Again, management need to heed to the requests, suggestions, and caution of staff and respond in a timely manner to ensure a peaceful and happy climate that will foster hardwork at all times. All these can be possible if managers are equipped with the necessary skills and insight required in handling employees.

6.2 THEORETICAL IMPLICATIONS

The globalization of markets, the rapid development of emerging markets, and response to competition worldwide has made the propositions in this paper very necessary, in that employers across the globe need to know how to effectively sustain their businesses by effectively managing their employees. The essence of the framework therefore transcends national and cultural boundaries , and serves to address a pressing issue of humanity. The framework also aids in this direction by adding to the body of knowledge in the field of management. It throws more light on factors that may lead to an organization experiencing a high turnover and If the model is tested and confirmed, it will serve as an effective tool to help management address the needs of their employees and thus obtain the best from them. Our conceptual framework contributes to a new and broader knowledge on employee turnover beyond that contained in the literature and how it can be curtailed.

7.0 DIRECTION FOR FUTURE RESEARCH

This paper made a proposition of a conceptual framework and did not examine (or test) it **in any particular field, but did an extensive** review of the literature to form its conclusions. It is therefore imperative for future researchers to actually conduct a case study or in depth interviews on the subject, to find empirical evidence to support or debunk the model. For instance, a study done in a company's setting may yield very rich and diverse findings which may go to improve the framework and also give managers the necessary insight that they need to work. In doing this, more refined or additional questions on the proposed framework might clarify aspects of the various propositions bringing out concrete findings. More intensive data gathering, of people in diverse fields of work could also validate results and expand our understanding of this framework.

This research has been exploratory in nature and yet its uniqueness is that it gives a voice to a long standing and ever present phenomena, that when taken for granted, can lead to the collapse of any highly reputable organization. More studies need to be done on the subject to delve more deeply into the framework and to better ensure that companies succeed. As research on this framework moves forward, it will be important to transfer what has been learned from research to teams, organizations, schools, hospitals and to any other establishment that deals with human beings to better their lot.

8.0 CONCLUSION

Structuring a positive working atmosphere is among the most significant responsibilities every administrator can assume. The working atmosphere plays an important function in encouraging staff to execute their allocated task, since money is not a satisfactory motivator in inspiring the organizational performance obligated in recent competitive business environment.

The capacity to fascinate, retain and persuade high-performance is becoming gradually significant in recent competitive organizational environments. Therefore, forming a harmonious workplace will increase efficiency and foster creativity between staffs, so they will be able to influence their potential. Also, treating staffs with admiration and presenting to them bonuses and rewards, will make them feel treasured and motivated, though endorsing self-development will permit them to work more competently.

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ARTICLE 2

Technology Development and Economic Transformation of Academic Entrepreneurs in Ghana

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Abstract

Today, the goal of any society is to alter its economic system. Technology has improved a number of economic sectors, including education. New forms of economic change as a result, such as the knowledge-based economy, have emerged. In order to alter themselves, business processes, industries, people, markets, communities, and economies, university professors must now make use of their competencies. There is a stronger chance of boosting established living standards in universities that use technology and teach career-related skills. The aim of this study is to ascertain how academic entrepreneurs' economic transformation is influenced by university lecturers' ability to progress through technology. Twenty-Four academic members from the Ghana Communication Technology University in Accra were purposefully chosen for face-to-face interviews. NVIVO 11 was used to categorise the data into themes and sub-themes. According to the report, faculty members are progressively starting to ascertain the advantages of using technology to share their research, create novel ideas, and promote their academic careers. Technology has increased faculty visibility on a global scale, and they predict that technology will be the future of research.

Keywords: Technology Development, Academic Entrepreneur, Economic Transformation

Introduction

Technology's quick development has increased innovation levels across a variety of worldwide businesses, including education. The knowledge-based economy is one of the newer forms of economic transformation that it has brought. The new economic transition was also referred to as an entrepreneurial mode of production by academics. In order to create jobs, faculty members must be transformational. To do this, they must have the skills and resources to change business practices, industries, markets, and economies (Baena-Luna, 2022; Kuratko et al., 2022; Liu & Dong, 2021). According to studies, the development of technology has the potential to significantly alter the economic status of the academic entrepreneur in a number of ways that were not first anticipated (Cao et al., 2020; Ye et al., 2021; Osborne, 2017). Professors with an entrepreneurial attitude and skill set have better prospects of economically changing themselves and most conditions than those without the necessary training (Sculac, 2021). Most people now view academics as essential drivers of economic development and progress because they provide the means by which the economy might change to become economically viable. In today's society, it is crucially important to cultivate entrepreneurial attitudes through acting and practicing entrepreneurship, such as through completing actual market-oriented initiatives in teams or cooperatives.

Researchers (Cardella, et al., 2021; Haseeb et al., 2020) recognise the contribution of technology to improving most economies. Thus, universities currently are the vehicles for cultivating sources of creative activities in that, they are industry dynamics, and have a significant potential for job production. Technology on the other hand has a variety of comparative advantages that increase

the faculty's competitiveness globally. Numerous sub-strands of literature on entrepreneurship and economic growth employ diverse metrics of entrepreneurial activity. For instance, while one line of empirical research measures entrepreneurship in terms of the relative share of economic activity accounted for by small firms, other research uses information on self-employment, the number of competitors in a market, or firm start-ups as an indicator of entrepreneurial activities (Midak et al., 2020; Sh, 2021). According to Zahra and Si (2022), academic entrepreneurs in developing countries can play crucial roles in reforming these economies due to their capacity to employ a sizable portion of the unemployed population and their propensity for nurturing.

The value of technological innovation and entrepreneurship for spurring prosperity and transforming nations has received relatively little attention, despite the many benefits of the academic entrepreneur. The use of newly acquired information to spur economic growth is severely flawed. Policymakers see university education as a private investment rather than a public good, and developments in the political economics of higher education have also contributed to this view (Sili & Dürr, 2022; Urbaniec et al., 2022). From a national viewpoint, it is vital to improving the faculty's use of technology in order to increase the visibility of our universities on a global scale. In terms of benefits to the economy and population, scientific research is gradually increasing from a national perspective. Ghana as a nation has not yet achieved this. Thus, it is now essential for university staff to look for new sources of income in addition to their insufficient wages and live better lives both now and when they are retired in order to balance their budgets. According to Stark et al. (2022), university lecturers are now presenting their work using technologies like social media, LinkedIn, Twitter, and Facebook in an effort to partner with outside stakeholders and monetize their research results. Despite this, there is little documentation regarding the realities and implications of commercialising academic products (Kollmann et al., 2022). As a result, little is known about how academia affects the development and application of technology. Additionally, it is challenging to comprehend the dynamics at the local, national, and international levels due to the paucity of empirical and theoretical studies on AE and economic transformation in relation to technology improvements in the nation. As a result, unsuitable policy frameworks are created. In light of this, the study seeks to comprehend the influence of technological advancement on academic entrepreneurs

This research is aimed at understanding the technology development of academic entrepreneurs, which in turn translates to the economic transformation of selected faculty members of Ghana Communication Technology University. Specifically, the objectives sought to:

- *Ascertain if technology is providing academic entrepreneurs.*
- *Explore the ways faculty members utilize technology to create visibility and economic opportunities.*
- *Examine how public-private partnerships influence the economic transformation of academics.*
- *Explore the future for the faculty with the upsurge of technologies in research.*

Theoretical Literature Review

Theoretically, experts in industrialised nations acknowledge that technology has a significant role in advancing the entrepreneurial economy. These technologies have a variety of dependent edges, increasing the academic entrepreneur's competitiveness on a worldwide scale. Things that nag academics draw their attention toward them because they are drawn to them internally. The push and pull idea has been used to explain why certain items act as incentives and pull us in the direction of obtaining them. According to this, entrepreneurial activity among academics requires both push and pull elements. According to the pull perspective (Han, et al., 2022; Kekezi, et al., 2022) faculty is drawn to the field for reasons such as market opportunity recognition, the desire to try something new, and the need to put theory into practice. The faculty is motivated to change by a variety of academic contextual push factors that are emerging. For instance, universities are forced to raise tuition prices due to declining government funding, and faculties are similarly pushed to look for income outside of their university, some of which can be attained through procurement of grants (Roy et al., 2022), in writing. Academics who work full-time are now encouraged to be academic productive by adopting an entrepreneurial mindset. From the standpoint of creating businesses, people do not do so by mistake (Villanueva-Flores, 2022). As a result, they are either forced or drawn to become entrepreneurs, just as in colleges.

Maslow's Theory of Hierarchy

One person's pull factor could be another person's push factor (Aurretsch & Belitski, 2022). The desire for achievement according to Maslow's hierarchy is that before any person experience self-actualization, that person must first satisfy their four basic needs of physiology, safety and security, social/belonging, and self-esteem. This idea places human needs in an ascending sequence and contends that everyone tries to meet their basic requirements before being motivated to meet higher-level demands (Dutil, 2022).

Empirical Literature Review

In terms of the **academic entrepreneur** and the university, this means that they are significant players in the process of producing and commercializing research output. On the basis of this notion, it is observed that business owners make endeavours to meet their own demands, which can vary from one business owner to the next. As a result, some entrepreneurs start enterprises to meet their basic wants, including the need to buy food and pay rent, as well as the belief that doing so will boost their self-esteem and enable them to meet more complex requirements (Fasi, 2022). This is how the academic entrepreneur sees it. Due to its connections to a number of well-established fields, including sociology, psychology, management, and economics, entrepreneurship is a multidisciplinary term. According to Cardella et al. (2021), entrepreneurship is expanding quickly and is defined operationally as the willingness of individuals, either alone or in groups, to create new economic opportunities. Additionally, their research shows how entrepreneurship spans a wide range of industries, including but not limited to those in education, technology, marketing, public policy, community development, and many more. As a result, it is fundamentally a personality trait.

Similar to this, it has been noted that AE is a multifaceted phenomenon influenced by a range of circumstances (Sculac, 2021; Eriksson, 2021; Karpinskaia, 2022). According to the experts,

universities are today an ideal source of concepts and fundamental technologies that support entrepreneurial ventures. An AE is described in this study as a lecturer or faculty who uses their academic expertise to produce information that is applicable to academia, industry, and society, creating value and money for themselves in the process. While still employed by the university, these faculties must be able to use technology to their advantage by publicly promoting their institution and themselves. By doing this, they can expand their network of business contacts. According to other research (Eriksson, 2021; Bigliardi, 2022; Hrivnák, 2022; Monge-Agüero, 2022), there is very little difference between opportunity identification and opportunity exploitation.

There is a dearth of knowledge regarding the elements that contribute to the growth of entrepreneurial abilities among academics and the transformation of the economy. We are considering knowledge, objects, and theoretical and practical abilities from a technological perspective in order to facilitate the production of goods and services. Technology, according to Ye et al. (2021), is embedded in objects, people, cognitive and physical processes, tools, machines, and infrastructure. Universities now need to focus especially on entrepreneurial research and technology transfer. The ability to discover how wealth can be made through technology is essential. Currently, it is estimated that top online tutors earn $17million per annum (Regmi, 2021). New academics need to be taught and supervised in opportunity recognition, and their research ideas must be tailored to the global market. However, high levels of inferred knowledge that spur commercial ideas that are the result of study frequently call for the early conception of such novel insights (Zhai, et al., 2022).

Understanding how university information is immediately transferred into a workable business is important (Gabrielsson, 2022; Landström, 2022). Due to their direct involvement, faculty members are the main carriers of research commercialisation in its early stages. The multiple people involved in the transfer of information and research output from the majority of universities to the industry are university professors and their peers. The academic hierarchy, according to ((Moortel, et al., 2022; Bigliardi,2022), places faculty in a position to expand their influence beyond their universities through activities like research and teaching ((Kulp, et al., 2022) and the commercialisation of technological innovation. This is in addition to having a network of contacts and being proficient in their fields. This will facilitate strong collaboration between academic institutions and businesses to produce fresh concepts for ongoing research (Wood, 2022).

Methods

Materials and Methods

In this study, a qualitative research methodology was used. This approach concentrates on topics that are pertinent and popular but lack in-depth and thorough explanations. Different methods in which these ideas and modifications can take place to demonstrate our familiarity with and understanding of them (Yarm et al., 2022). In this study, the phenomenological pattern was used to explore the idea of AE and ET in the evolution of technology. It aims to improve understanding of the relationship. The data collection method was by Interview. Semi structured interview guide

was used as instrument to gathered information from ten academics from GCTU in the Greater Accra Region were. The respondents were interviewed one on one. NVIVO 11 software was used to analyse the data for the results.

Research Design

In ascertaining the technology development and economic transformation of academic entrepreneurs in Ghana. This research adopted exploratory research design.

Sampling and Sample Procedure

The study employed a purposive sampling approach to select 24 academics from the Ghana Communication Technology University. The faculty members have at least eight (8) years of experience with the university due to their depth of knowledge. . The "information power" idea was reportedly utilised to choose the sample size, according to Malterud, Siersma, and Guassora (2015, 2). They recommend using this concept as a guideline for deciding on the proper sample sizes for qualitative analysis.

Data Collection

The study largely used primary data, by conducting one on one to gather information from the respondents. As a result, using themes taken from the literature, an interview guide was created for this aim. Participants were given the opportunity to discuss the research articles that they had produced for financial advantage in the first section. The university's activities and how they contributed to its visibility abroad. In the second section of the interview guide, respondents had the opportunity to explain in their own words the various tools and how they support the visibility strategy of their university as well as public-private partnership influence on the economic transformation of academics. Once more, transcribed interviews were provided to a subset of chosen respondents afterward to ensure that what they had stated had been appropriately recorded in the transcription. Recording, transcription, and coding of the data were done in that order.

Ethical Consideration

Due to the ethical nature of the research processes, all participants' consent was sought before the study began. The study's purposes and goals were explained to the participants. Additionally, participants were made aware that taking part in the study was entirely up to them and that they had the freedom to stop at any time if they so desired. After then, participants were given the assurance that the researchers would respect their privacy and regard all of the information they had submitted as confidential. De-identification with codes or Pseudonyms was done with the data obtained. Access to files on laptop computers and the recordings of interviews were password-protected, and data was carefully secured. After being contacted, respondents were asked what time and day would work best for them. Then it was decided to have a meeting. The secrecy of their answers was guaranteed, and the interview location was left up to the respondent's preference.

Results and Discussions

The analysis produced five themes after transcription. Table 1 summarises the key themes identified from the data. This is followed by the description of the themes and illustrative quotations. Pseudonyms were used to preserve anonymity.

Table 1: Summary of key points identified

Theme	Summary of key points identified
Exploring technology to become an academic entrepreneur.	Opportunity to be an academic entrepreneur through research.
Technology creates visibility and economic opportunities.	Technology is essentially making academic researchers internationally visible
Access tools for international visibility	I use international visibility tools for publication
Academics and industry collaboration for social-economic development	Public-Private partnership a catalyst for academic socio-economic development
Understanding the use of technology, and the future of research.	Technology has an influence on future academic academic work

Technology Development: **Exploring technology for academic entrepreneurs**.

All the participants reported that they have been using technology and have seen its usefulness in making them academic entrepreneurs. Illustrative examples appear below.

Kwaku Mensah 1: "*I saw an opportunity to commercialize some findings from my ongoing Ph.D. dissertation. I currently own a company that coaches people to become entrepreneurs through research (Personal Communication. 15th June 2023)"*

Yaa Amponsah 2: "*I use technology to provide quality teaching to keep my job. However, since my salary is not enough and therefore cannot do much to sustain me economically, I vigorously pursue research that has the potential to generate new products/services for commercialisation, and for sale of the research findings in the form of articles and books. I also consult to the service*

economy out of my research findings and academic/industry experiences through which I can earn more money. (Personal Communication. 15th June 2023"

Yaw Manu 3:" *Technology helps me to commercialise my research findings. The number of academic publications will aid in my academic promotion and hence sustain my economic future. The application for grants will also help in my economic sustainability. (Personal Communication. 15th June 2023"*

Sam Jones 4: "*Technology ensures speed in research and teaching and has been useful in providing consultancy services to industries. (Personal Communication. 15th June 2023"*

Abena Asante 5: "*Academics are interested in deriving personal pay-offs from the commercialization of their knowledge and technologies (Personal Communication. 15th June 2023".*

Kwabena Botchway 6: "*Good academic productivity will lead to good visibility and good visibility will improve your chance of obtaining research grants, getting lucrative consultancy contacts, etc., which can open doors to a brighter economic future. (Personal Communication. 15th June 2023"*

Johnson Brown 7: "*The practice of consulting may be another tool for interactive knowledge transfer between academics and decision-makers, one that is particularly effective at promoting the enlightenment and interactive models of knowledge use, which to most academic researchers may be less familiar than instrumental models (Personal Communication. 15th June 2023".*

One participant however, reported that there could be no tremendous economic change, but at least some economic gains are associated with promotions.

Technology creates visibility and economic opportunities:

In their accounts, most participants highlighted how technology has improved their visibility and economic opportunities.

Abena Asante 5: *"My ability to continuously do scientific research and make it more accessible means publication in scholarly journals, books, and so on (Personal Communication. 15th June 2023".*

Kwabena Botchway 6: "*Technology has greatly improved academic output in terms of research and publication as well as improving the visibility of published research. It enhances my ability as an academic to cooperate, thereby creating better opportunities for academics across the world to work together, improving the quality of research. (Personal Communication. 15th June 2023*"

Johnson Brown 7: "*Engaging in consultancy enhances my value and gives me the opportunity to have an impact on society and be relevant as an academic entrepreneur (Personal Communication. 15th June 2023".*

Sam Ampadu 8: "*My publications have won me a research grant by collaborating with others within and out of the country. (Personal Communication. 15th June 2023"*

Owusu Asante 9: "*My academic productivity has opened doors for international projects and consultancies increasing my visibility for financial gains and knowledge dissemination (Personal Communication 15th June 2023"*

From above assertions, it was evident that the participants highlighted how technology has improved their visibility and economic opportunities.

International visibility Tools

Almost all participants claimed to have used various platforms to increase their visibility on a global scale for financial advantage. Publications, preprints, conference papers and posters, presentations, research data, videos, and code document research activities. By making these materials publicly available, researchers can raise awareness of their work, preserve their results, and make them accessible for use in the future.

When submitting their manuscripts and data, the respondents indicated using individual author identification. When it comes to their research output, some researchers are inextricably bound to their authors. Some people have made and used an impactStory, a web CV, a google scholar citation profile, or an updated online profile. Some participate in online groups for social networking, including LinkedIn, Research Gate, and Academia.edu. Tweet, Research Blogging, and ORCID are further resources.

Kwaku Mensah 1: "*I utilize ORCID, Research Gate, GoogleScholar, Linkedin, Research blogging and many others (Personal Communication. 15th June 2023".*

Yaa Amponsah 2: "*ORCID, ImpactStory and Research Gate, Linkedin (Personal Communication. 15th June 2023"*

Yaw Manu 3: "*Google Scholar, Academia.edu, ORCID (Personal Communication. 15th June 2023".*

Johnson Brown 7: "*Many academics and researchers looking for cooperation find ResearchGate to be the ideal research tool. I read updates from peers who share my interests or from professionals. I receive notifications when others read or quote my articles, and I also receive notifications when people I follow publish new studies. I can write to other members and ask for the full text of any articles they have mentioned. ResearchGate based on my profile and publications also generates an RG score. This is distinct from the citation score provided by journals or the H-score calculated by Google Scholar. Overall, ResearchGate is a great*

research tool if you want to monitor your colleagues' work and work with various institutions (Personal Communication. 15th June 2023".

Academics and industry collaboration for social-economic development:

The third theme is how university lecturers can team with industry players to research using technology to improve social-economic development.

Participants noted more understanding of collaboration for social-economic development.

Sam Ampadu 8*: "I believe academics need to collaborate with the industry for economic and social development (Personal Communication. 15th June 2023".*

Owusu Asante 9: "*This is not only necessary but also essential. The industry does not benefit from our research outputs if we do not consult with them unless our research works have no alignment with the needs of the industry. There is a need for more application-based research so that we are able to be more answerable to the needs of the industry. Consulting with the industry is one of the surest ways to be informed about what is happening in the industry in terms of their human resource needs and the problems they face so as to guide our teachings and training of our students for industry."*

Jane Kwame 10: "*Academia is a knowledge hub that can benefit industries. They produce the human capital that is engaged in the industries (Personal Communication. 15th June 2023".*

Kwaku Mensah 1: "*This will help to bridge the gap between the academic and industry and impact on the course content of the academic programmes (Personal Communication. 15th June 2023"*

Yaa Amponsah 2: "*Industry will see commercial value in research output and will seek to commercialise them (Personal Communication. 16th June 2023)".*

Yaw Manu 3: "*This will help to bridge the gap between the academic and industry and influence the course content of the academic programmes. (Personal Communication. 16th June 2023"*

Sam Jones 4: "*Engaging in consultancy enhances my value and gives me the opportunity to have an impact on society and be relevant as an academic entrepreneur (Personal Communication 16th June 2023"*

Understanding the use of technology and the future of research.

All the participants believe technology is the future of research.

Johnson Brown 7: "*Technology will simplify my academic productivity. I do not have to travel to collect data. Time spent on writing articles will reduce drastically. There are a lot more tools available for data analysis now than it is used today. (Personal Communication. 16th June 2023"*

Sam Ampadu 8: "*It will be a catalyst to engage in more research ((Personal Communication 16th June 2023"*

Discussions

The Ghana Communication Technology faculty was used as a case study in the study, which ascertain the technological progress of AE that later led to the ET of the faculty in Ghana. The responses confirm that academic entrepreneurs use technology to brand themselves as faculty members. This corroborates the study's finding (Sculac, 2021; Eriksson, 2021; Karpinskaia, 2022) that academic entrepreneurship is a multifaceted phenomenon influenced by a number of variables and that it serves as a prime source of concepts and essential technologies for initiatives to promote

entrepreneurship in universities. However, there was one opposing viewpoint that there is no tremendous economic change, but at least some economic gains are associated with promotions. All the participants reported that technology through their research publications has made them internationally visible in high-index journals.

The importance of research promotion initiatives is growing in researchers' daily activities. Making your research visible and approachable increases the likelihood that it will be found, utilized, and have an impact, enhancing your reputation and chances of academic success. To promote their work, communicate with other researchers, and participate in academic discussion, researchers are embracing a variety of activities and methods. More and more, researchers engage in marketing-related activities at every level of the research process, from discovery through analysis and writing to publishing, outreach, and assessment. Respondents offered a thorough map of how technology-enhanced research has made them visible through the use of both older and more modern research methods. There were accounts of heightened visibility and a resultant effect on business opportunities. Many people have been able to use technology to their advantage by using it to promote themselves and their institution overtly, boosting their business relationships in the process. According to the report, many individuals use a variety of strategies to make themselves known to potential employers.

Initiatives for promoting research are becoming increasingly important to researchers' daily tasks. The reputation and chances of academic success will improve if one makes your research accessible and visible so that it may be found, used, and have an impact. Researchers are embracing a variety of activities and strategies to publicise their work, connect with other researchers, and take part in academic conversations. At every stage of the research process, from discovery through analysis and writing to publishing, outreach, and assessment, academics are becoming more and more involved in marketing-related activities. Using both traditional and cutting-edge research techniques, respondents provided a complete map of how technology-enhanced research has made them visible. There have been reports of increased visibility having an impact on commercial opportunities.

Many people have been able to take advantage of technology by aggressively promoting themselves and their institution through it, to solidify their professional relationships. According to the report, faculty is to introduce themselves to potential employers and frequently use a variety of strategies. High-quality research must be simple to find in order to receive the attention it merits. There is evidence that the aforementioned actions boost discoverability and citations. In conferences and, where applicable, at international congresses, presenting research findings. The opportunity to network and form new partnerships is another benefit of attending such events. Participants advertise their study on social media and through networks to a larger audience. Twitter, Academia.edu, and Linked-in are a few examples.

Using citation data, researchers can compare journals that are indexed in the Web of Science using Journal Citation Reports (JCR). JCR displays the journals with the most effect on the subject. Additionally, a free Scopus-based database called SCImago Journal and Country Rank (SJR) is

available. Based on the caliber and standing of journals, it offers a prestige metric (SJR). It appears in Scopus Journal Metric (PDF). Impact scores using Scopus 'compare sources feature can sort journal titles in a subject area. According to them to locate high-impact journals in the Scopus database has been supportive. With the help of this tool, academics can compare journals based on reported CiteScore, SJR, or SNIP scores. A reader's comprehension of the research's substance is improved by the careful use of keywords in both the abstract and the full text. This might also make researchers more visible in search results. The authors you cite might work with you again in the future and cite you.

The study found out that collaborative research with industry has the potential for cross-disciplinary idea exchange, the acquisition of new skills, access to money, improved outcomes, radical advantages, and individual elements like fun and pleasure. An interdisciplinary team of researchers can frequently resolve the majority of the most pressing scientific problems or cutting-edge technology. The cooperation between academics, institutions, companies, and/or communities might enable the attaining of great aims through the combining of different fields. This could help to develop unique expertise. Consortia, federation, affiliation, and merger can happen at five distinct levels even if collaboration is voluntary. They fall under disciplinary, interdisciplinary, trans-, multi-, or multi-disciplinary categories, or they are national versus international. However, research that is conducted in partnership introduces fresh knowledge and concepts from different fields, produces high-quality results despite individual considerations like enjoyment, and has easier access to funding. Participants asserted that:

1. Through collaboration, open lines of communication are established, and participants are urged to seize possibilities for the renewal of antiquated systems;

2. Invoking all teammates and others to participate in self-reflection and offer criticism.

3. In order to better understand cause and effect, stakeholders who can act as a feedback loop should be identified.

4. Working together clarifies roles and duties.

5. To create a professional workplace and respect various organisational cultures.

The following were also identified as different kinds of collaboration such as intradisciplinary (team of researchers within the same department). Interdisciplinary (team of researcher of different departments but different background), multidisciplinary (team of researcher of different background), or transdisciplinary (involvement of people from outside academia into the research process) and everyone aspires for common demands such as making operational plans, communication between different research groups, sharing of credit and money, holding frequent meetings, and encouraging open communications.

Conclusion

Finally, yet importantly, it is clear how technology will be used in future research, and participants didn't hesitate to respond, suggesting that it is in fact a catalyst for academic entrepreneurs. Faculty members are gradually becoming aware of the value of utilising technology to disseminate their research, develop novel ideas, and advance the field of study while also gaining financial independence. All of a faculty's entrepreneurial aspirations are tapped into through technology, making scholars more accessible and helpful.

Research practical implications

The twenty-four-sample size for this study is quite small and the effects of covid-19 have made respondents reluctant to participate in face-to-face interviews.

According to Kekezi et al. (2022) and Han et al. (2022), faculty are attracted by things like the desire to apply theory in the real world, the desire to attempt something new, and the recognition of commercial opportunities. The faculty is motivated to change by a variety of academic environmental push factors that come from the push perspective. Universities, for instance, are forced to raise tuition fees due to declining government financing, and faculty are similarly pushed to look for income outside of their organisations. Academics who work full-time are being urged to think entrepreneurially. From the standpoint of venture formation, people do not only get engaged (Villanueva-Flores, 2022). As a result, they are either encouraged or pressured to start their own business, exactly like universities. This data supports the push-pull theory and suggests that faculty members are currently striving very hard to become AE because of the rapid advancement of technology and changes in the economy. Our research supports the need for accomplishment theory, which states that before moving on to the highest degree of demands in the hierarchy, faculty members start businesses to meet their particular wants (Fasi, 2022). This is from the standpoint of a potential academic entrepreneur.

Therefore, universities must foster a supportive environment while enhancing their technology support so that lecturers can project their research, develop industrial partnerships, and thereby eventually promote their institutions locally and internationally.

Social implications

The study thus suggests that Ghana Communication Technology University's technology infrastructure be improved, and it encourages faculty to work more closely with industry to gain a deeper understanding of how it operates and how it is practiced. By doing this, it will also provide opportunities for the majority of staff to start their own academic businesses. In practice, this will increase the set living standards for academics both now and in the future and make them more economically viable.

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ARTICLE 3

System Design of an Electric Meter with a Password Interface to Control Unauthorized Access

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Abstract

Disconnection is the deliberate and temporary curtailment of power supply to the premises of customers because of non-payment of bills illegal connection or unauthorized extension of supply. After the disconnection of meters at the customer's residence, some customers reconnect their meters after the electricity provider has disconnected their meters. This causes a loss in revenue to the electricity provider. In this paper, we propose an electric meter with a password interface. With such a meter, a password would be required to turn on or off the meter. This will prevent reconnection of electric meters by customers who owe the electricity company.

Introduction

Electric utilities utilize electric meters connected at customers' locations to quantify electric energy distributed to their customers for billing purposes (ECG, 2016). They are classically calibrated in billing units, the most widely recognized one being the kilowatt-hour (kWh) which is typically perused once each billing period. At the point when energy savings amid specific periods are wanted, some meters may gauge the demand, the most extreme utilization of energy in some interim. "Time of day" metering allows electric charges to be changed amid a day, to record energy usage amid peak high-cost periods and off-peak, lower-cost, periods. Likewise, in a few territories meters have relays for demand response load shedding amid peak load periods.

As indicated by the Electricity Company of Ghana (ECG) (2016), an unlawful connection is tapping electrical power from the Electrical Mains which has not been endorsed authoritatively, or the reconnection of lawfully detached premises without authorization. The accompanying exercises go under illicit association characterization (ECG, 2016): unlawful direct interface, illicit meter exchange, meter altering, meter bypass, illegal network extensions, unlawful conveyance of service supply, and self-reconnection after disconnection. In literature, numerous examinations have been conducted in different nations on the unlawful utilization of electricity. For instance, Min and Golden (2013) examined the impact of illicit power use on an Indian state. Onat (2010) clarified that an electric energy system cannot give 100 percent output without losses. The author brought up that the cost of illicit power use was 14.4% which is 1.7 times Turkey's speculation on yearly transmission and distribution system. Gaur and Gupta investigated panel data collected from 2005 to 2009 of 28 Indian states by applying Feasible Generalised Least Squares and Ordinary Least Square regression models to identify the determinants of electricity thefts in Indian states and concluded that more than 20% of total electricity generated in India is lost to thefts. In addition, the authors concluded that socioeconomic and governance factors play a major role in this unfortunate incident.

In Ghana, on the other hand, such studies are rare, however, reports from ECG indicate that a high percentage of revenue losses can be attributed to unlawful connections (Kanarku, 2016). The following were some reports by ECG on unlawful connections and arrests:

- Electricity illegal connections: 52 offenders caught in Accra West (ECG, 2023)
- ECG discovers 130 illegal electricity connections in Ashaiman District (ModernGhana, 2024)
- The Electricity Company of Ghana (ECG), Ashanti West Region, uncovered 74 illegal connections during the first quarter of 2024. (CitiNewsRoom, 2024)

Disconnection is the deliberate and temporary curtailment of power supply to the premises of customers as a result of non-payment of bills unlawful connection or unapproved expansion of supply. However, after the disconnection of meters at the customer's residence especially post-paid meters, some customers reconnect their meters after the electricity provider has disconnected their meters due to accumulated unpaid bills. This causes further losses to the electricity provider. According to ECG, the following were recovered from illegal connections i.e. tempering with meters and bypassing of meters:

- Ghana: Over $600,000 lost in nine months through illegal power connections (Mbillah-Lawson, 2023)
- ECG loses $400m to illegal connections – Energy Minister (Amoah, 2022)

The Northern Electricity Distribution Company (NEDCo) also reported losing GH¢3.7 million to illegal power connections and recovered GH¢1.5 million. (Ghanaweb, 2024). There is a need to put an interface on the meter that will prevent reconnection of customers who owe the electricity company. Therefore, this study proposes an electric meter with a password interface to control unauthorized access to electric meters by users.

Concept of Electricity Meters

An electric meter is a device that quantifies the amount of electric energy used by a home, a business, or an electrically controlled device (García, 2012). Electricity Company of Ghana (ECG) utilizes energy meters installed at customers' premises to quantify electric energy conveyed to their customers for billing purposes. They are calibrated in billing units kWh. Meters of various precision classes are utilized for various purposes and applications (e.g. Private, Nonprivate, Industrial, and so forth.) in view of the exactness necessity. By and large, two broad kinds of meters are being used in ECG: whole current and transformer-operated

A. Whole Current Meters

These meters are associated directly with the residence (private and non-private) to be measured. They are used for Residential and Non-Residential clients with low energy requirements. Extensively, they are grouped by the technology used and are as per the following: Electromechanical and Electronic.

i. Electromechanical

The Electromechanical Meter functions by counting the revolutions of a non-magnetic, but electrically conductive, metal disc which is made to rotate at a speed proportional to the power passing through the meter. The quantity of revolutions is thus relative to the energy usage. The voltage coil devours a small and relatively persistent amount of power, usually around 2 watts which is not recorded on the meter. The current coil likewise devours a small total of power in proportion to the square of the current flowing through it, usually up to a couple of watts at full load, which is recorded on the meter. The electromechanical meters are all credit meters and are usually: A single-phase credit meter and Three three-phase credit meters.

ii. Electronic

Electronic meters show the energy utilized on an LCD or LED display, and some can also transmit readings to remote places. These meters work by counting impulses and therefore have ratings of impulses per kWh which vary from manufacturer to. Notwithstanding calculating the energy used, electronic meters can also record other parameters of the load and supply such as instantaneous and maximum rate of usage demands, voltages, power factor reactive power used, etc. They can likewise bolster time-of-day billing, for instance, recording the measure of energy used during on-peak and off-peak hours. These meters are manufactured as either credit or prepaid and may be supplied as follows: Single phase credit meter, Single phase prepayment meter, Three phase credit meter, and Three phase prepayment meter. Electronic meters are generally of accuracy class 1, i.e., ±1% variation of the nominal value.

B. Transformer Operated Meters

These are meters usually interposed (not connected directly) at the entry of the circuit to be quantified. Transformer-operated meters are usually of the three-phase grouping and are developed for demand above 70kVA (or 100A). Usual customers are SMEs

and extensive non-residential customers such as hotels, restaurants, schools, hospitals, etc. The meters have exactness classes of 1.0, 0.5, and 0.2 reliant on the metering application. They may be either electromechanical or electronic.

Related Works

Veena et al. (2015) also developed a user-changeable password-based circuit breaker. The main component in the circuit is 8051 microcontrollers. The keypad was utilized to enter the password. The password, which is entered, is matched with the predefined password. On the off chance that the entered password is correct then the parallel electrical line is turned on or off. Raza and Naitam (2017) developed a password circuit breaker to safeguard the safety of the maintenance staff. The line could be turned off and on by a lineman. This system provides an avenue where a password is required to operate the circuit breaker. However, these works were not considered for electricity meter application.

Methodology

This section consists of the software design and hardware design.

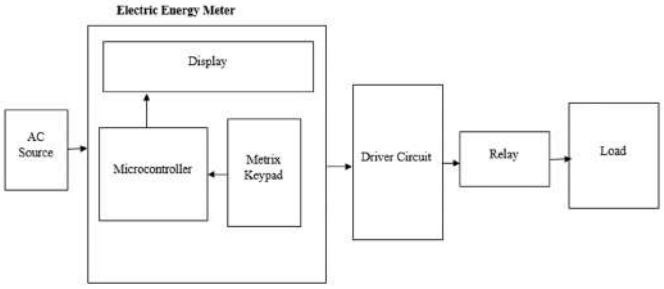

Figure 1. Block diagram of the electric meter

Software design

Proteus 8 Professional software was used to design and simulate the circuit diagram in Figure 1. The Keil µ was utilized to compose a program in assembly language in a text editor, amassing the written program in a compiler and finally producing a hex code from the compiled program. An Arduino Uno microcontroller connected to an LCD and Matrix keypad with a driver circuit connected to a relay that controls the meter (indicated as load). Other equipment parts required such as a lamp, tAT89C51, and an AC source were implemented to achieve the objective of the study.

Simulation and Results

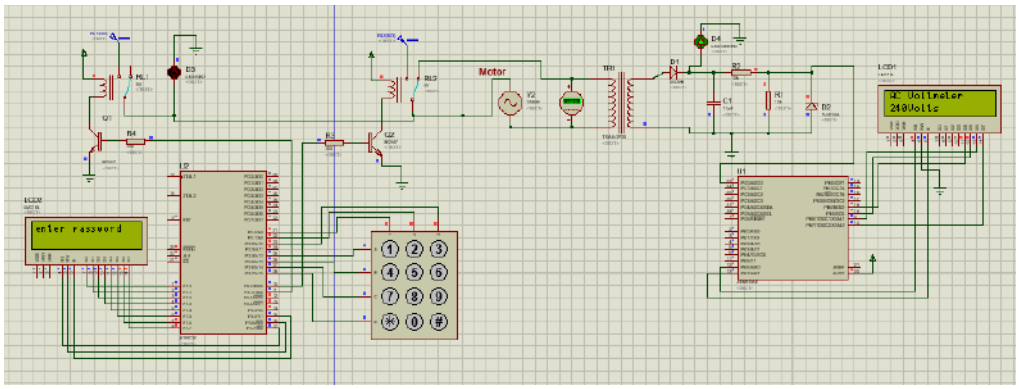

Figure 2. Active meter reading 240volts

Figure 2. Shows the electric meter in active mode with readings of 240 volts and the password interface ready to receive a password to switch off the meter. The green LED (D4) is always on or Blinking whenever the meter is active and the red LED (D3) comes on when the meter is deactivated.

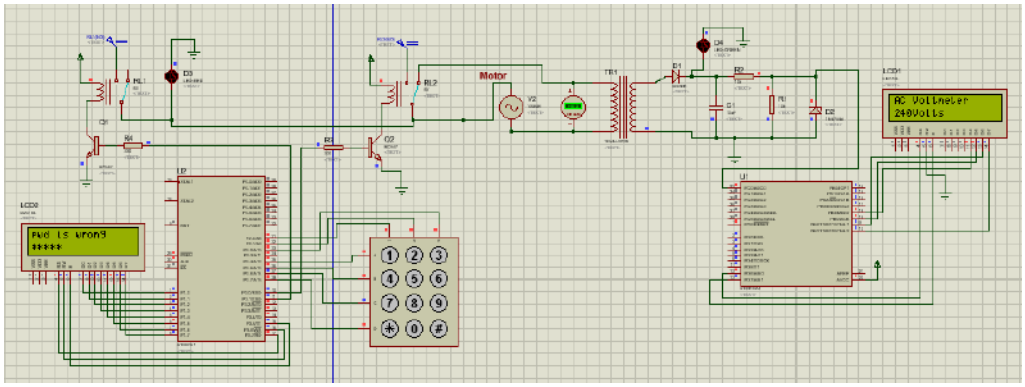

Figure 3. Wrong password entered with meter active

Figure 3. shows the electric meter in active mode with readings of 240 volts. A random password was entered but access to the system was denied. This can be seen on the password interface as "pwd is Wrong". No password can be allowed apart from the required password.

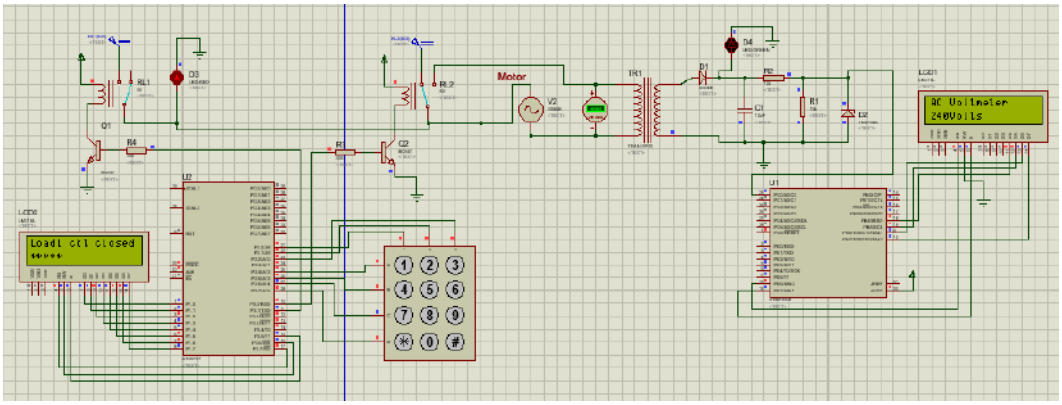

Figure 4. The correct password was entered with the meter preparing for deactivation

Figure 4. shows the correct password entered. This can be seen on the password interface as “load closed” which means the relay. The switch to the meter circuit has been turned off. As a result the green LED (D4) indicator goes off and the red LED (D3) is turned on.

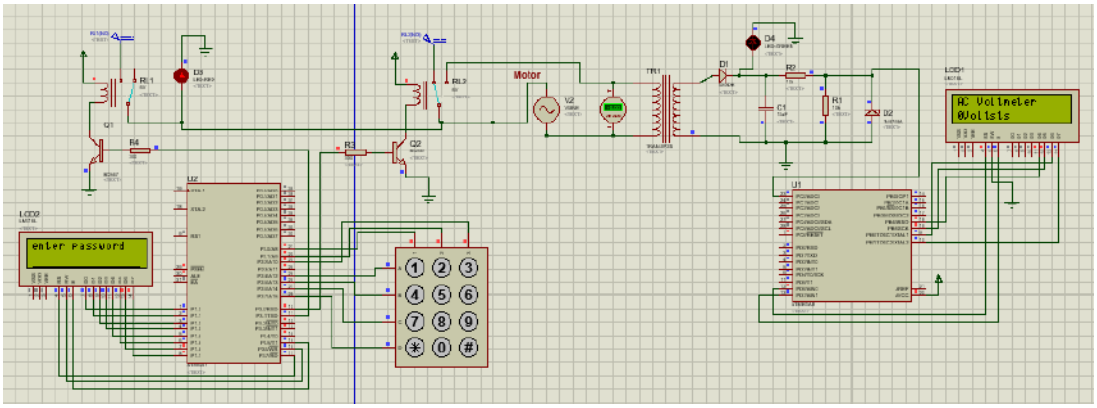

Figure 5. The meter was finally deactivated with a red LED indicator

Figure 5. shows the electric meter in deactivated mode with readings of 0 volts and LED (D3) turned on.

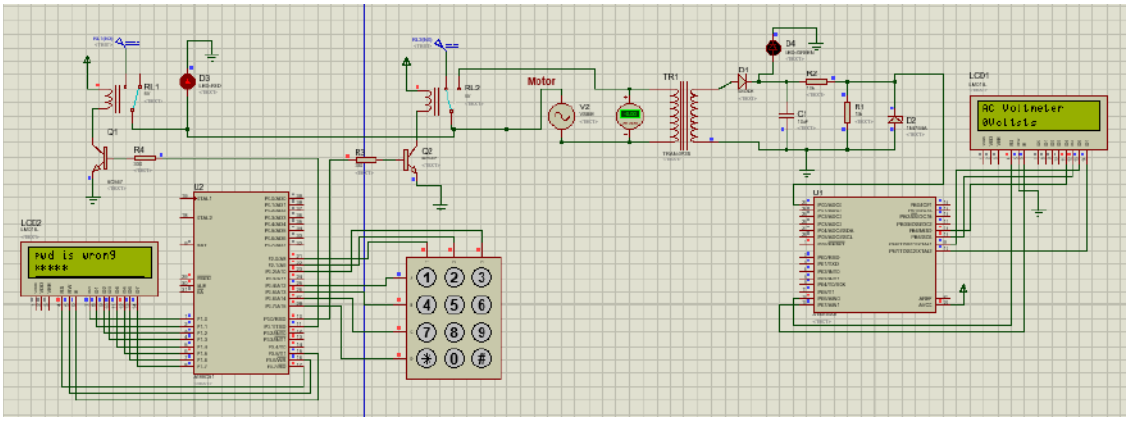

Figure 6. Wrong password entered with meter deactivated

Figure 6 shows the electric meter in deactivated mode with readings of 0 volts. A random password was entered but access to the system was denied. This can be seen on the password interface. As “pwd is wrong”. In the case, of putting the meter in an active mode no password can be allowed apart from the required password.

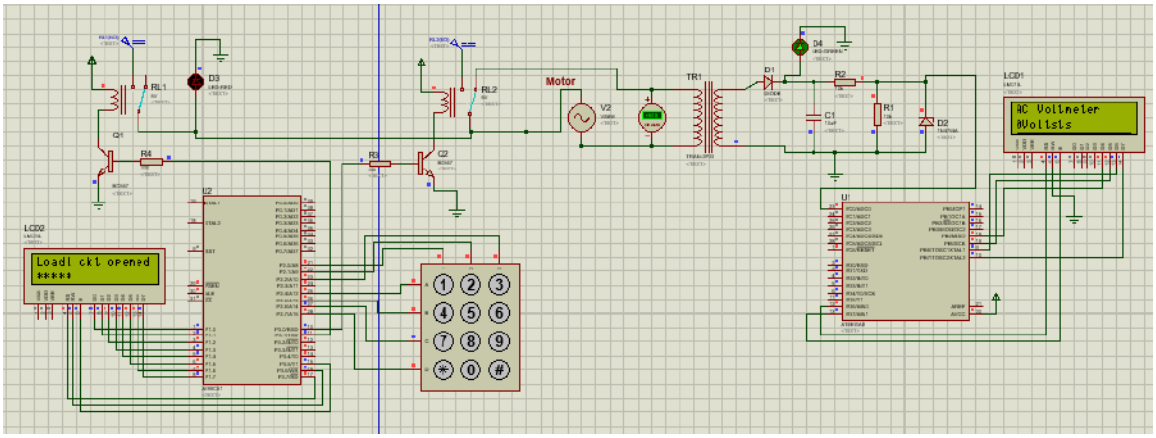

Figure 7. The correct password entered with the meter went active

Figure 7. shows the correct password entered to turn on the meter. This can be seen on the password interface as “load opened” which means the relay switch to the meter circuit has been turned on. As As a result the green LED (D4) indicator comes on and the red LED (D3) goes off.

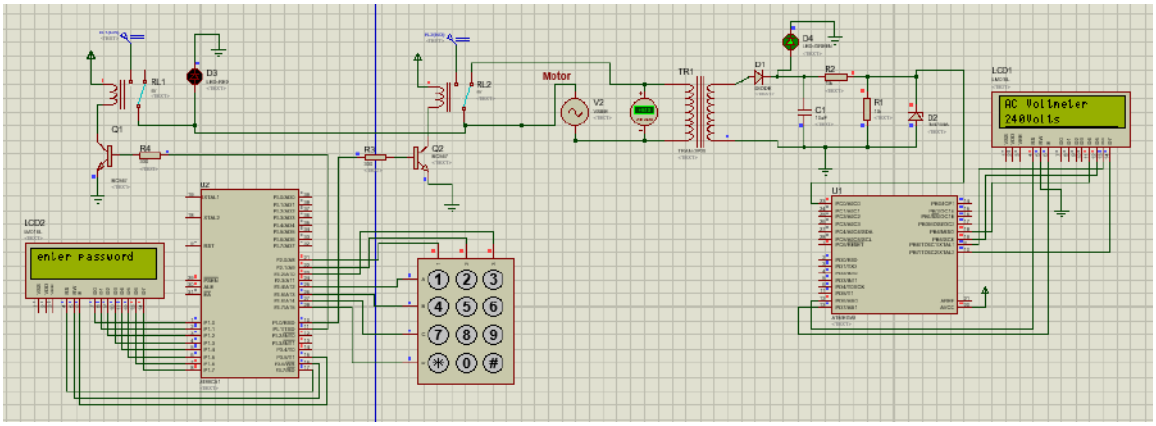

Figure 8. The meter finally active with a green LED indicator

Figure 8. shows the meter finally activated with a meter reading of 240 volts.

Conclusion

The study has demonstrated that when the system is implemented reconnection of electric meters by customers who owe the electricity company would be effectively controlled. The following future works are currently being considered;

- Hardware implementation of the system and controlling the system remotely.

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ARTICLE 4

Optimizing Telecommunications Network Performance: A Comprehensive Review and Analysis

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Abstract- This study presents a comprehensive review and analysis of strategies for optimizing telecommunications network performance in the context of rapidly evolving technological landscapes and increasing user demands. As the proliferation of mobile devices, IoT applications, and high-bandwidth services continues to escalate, network operators face significant challenges in maintaining efficiency, reliability, and quality of service. The research systematically examines various optimization techniques, including traffic management, resource allocation, and quality of service (QoS) enhancements. It highlights the role of Artificial Intelligence (AI) and Machine Learning (ML) in enabling predictive analytics for dynamic network management. The study also explores the impact of Software-Defined Networking (SDN) and Network Function Virtualization (NFV) for adaptable and scalable network architectures that are sensitive to fluctuating demands. Furthermore, the study reviewed the significance of big data analytics in user behavior and traffic patterns for informed decision-making in network planning and optimization. Security considerations are also addressed, emphasizing the need for robust protocols to safeguard network integrity and user privacy amidst growing cyber threats. The findings of this research underscore the necessity for a holistic approach to network optimization that integrates technological advancements with strategic management practices. Additionally, collaboration among key stakeholders is essential for fostering continuous improvement in telecommunications networks.

Keywords- analysis, optimizing network performance, telecommunication networks, measuring and monitoring, traffic, enhancing

I. INTRODUCTION

High network performance is important in telecommunications because it provides reliability, speed, bandwidth, Quality of Service (QoS), scalability and security. Overall, network performance is essential for delivering reliable, high-quality, and secure telecommunications services that meet the needs of users and businesses in today's digital world. Investing in network infrastructure and monitoring network performance are key strategies to ensure optimal service delivery and user satisfaction.

Wireless technology for mobile cellular communication has evolved from the First Generation (1G) in the 1980's to 5G and beyond as we have it today. The telecommunication network 1G was followed by 2G in the 1990s, 3G in the 2000s and 4G in the 2010s [1,2]. Each technology played a critical role within its period of operation leading to the development of the next level till today. For instance, 1G enabled analogue voice communication and mobility, 2G introduced digitized voice communication with text or SMS transmission capabilities and increased efficiency through enhanced multiplexing techniques such as GSM and CDMA. Even though network speeds were of the order of 10 kbit/s, it was the best at the time. 3G came as an improvement over the former, enabling better power consumption, enhanced handover and increased users within the system. Aside ushering in the mobile broadband at rates around a few Mbps, 3G was pivotal in the smartphone revolution. According to [2], the 4G technology brought about the revolution in the internet video sharing. Finally, the coming into being of 5G with speed reaching 2Gbit/s and less than 1ms latency, triggered Internet of Things (IoT) for manufacturing, smart cities, smart grid among others. telecommunications network optimization and highlight key strategies for improving network performance [3].

Optimizing telecommunications network performance is a critical area of research, especially as demand for high-speed internet and reliable communication services continues to grow. While there has been significant progress in this field, there is limited understanding of how to balance QoS requirements with network efficiency, especially in heterogeneous networks. Also, the integration of Machine Learning (ML) and Artificial Intelligence (AI) for predictive maintenance and performance optimization is still in its infancy. Furthermore, the role of edge computing in optimizing network performance is not fully understood, especially regarding latency reduction and bandwidth management. Finally, optimizing network performance often overlooks security implications, leading to vulnerabilities. The main aim of this research is to fill the afore mentioned gaps. The significance of optimizing telecommunications network performance lies in its multifaceted impact on user satisfaction, operational efficiency, scalability and flexibility, security resilience, sustainability via reduced carbon footprint, competitiveness, and adaptability to future technological advancements and challenges.

II. FACTORS AFFECTING TELECOMMUNICATIONS NETWORK PERFORMANCE

A. Bandwidth: Understanding the role of bandwidth in network performance

Bandwidth is critical in the determination of performance and efficiency of a telecommunication networks. Bandwidth may be defined as the maximum rate of transferring data across a network, the basic units are bits per second (bps) or megabits per second (Mbps) [4]. A higher bandwidth allows for faster data transmission, enabling users to access online services, stream multimedia content, and communicate in real-time more effectively. According to [5], bandwidth consumption can be defined as utilizing a networks transmission capacity to transfer data from source to destination within the network, over a particular period of time. It is confirmed that, the total bandwidth harnessed in a network at any given time is smaller than the theoretical maximum rate of data transmission.

Bandwidth can be measured as: Bandwidth (bps) = (Total amount of data transferred) / (Time taken to transfer the data). For instance, when 1 GB of data is transferred in 60 seconds, the bandwidth is calculated as: Bandwidth (bps) = (1810^9 bps) / (60 s) = 1.33 * 10^8 bps or 133 Mbps. Another method for measuring bandwidth is the use of the Speedtest tool, which evaluates the actual rate of data transfer between a server and client. In this case, the download and upload speeds of the network are measured and displayed in Mbps. The following are key points to understand the role of bandwidth in network performance:

1. **Data Transfer Speed:** Bandwidth directly impacts the speed at which data can be transmitted between devices on a network. Higher bandwidth means faster data transfer speeds, reducing latency and improving the overall user experience.

2. **Capacity**: Bandwidth determines the capacity of a network to handle multiple concurrent users and data-intensive applications. Networks with limited bandwidth may experience congestion and slower speeds during peak usage times.

3. **Quality of Service (QoS):** Bandwidth allocation is essential for implementing QoS policies that offer priority to some traffic against others. QoS management ensures that critical applications get sufficient bandwidth to maintain performance levels.

4. **Streaming and Multimedia**: High-bandwidth connections are necessary for streaming high-definition video, audio, and other multimedia content without buffering or interruptions. Insufficient bandwidth can result in degraded video quality and playback issues.

5. **Cloud Services:** Bandwidth is critical for accessing cloud-based services and applications, as data needs to be transferred between local devices and remote servers efficiently. Adequate bandwidth ensures seamless connectivity to cloud resources.

6. **Remote Work and Collaboration**: In today's digital workplace, remote work and collaboration tools rely on sufficient bandwidth for video conferencing, file sharing, and real-time communication. Low bandwidth can hinder productivity and communication effectiveness.

7. **Network Performance Optimization:** Optimizing bandwidth usage through traffic shaping, compression, caching, and other techniques tend to enhance performance of network performance, trigger latency reduction, and improve overall efficiency.

8. **Future Technologies:** Emerging technologies like 5G networks, IoT devices, and AI-driven applications will place increasing demands on bandwidth. Network operators need to continually upgrade infrastructure to support these technologies and deliver optimal performance.

To conclude on this, it must be noted that bandwidth is a critical factor in determining the performance, capacity, and reliability of modern telecommunications networks. Network operators must carefully manage and allocate bandwidth resources to meet the evolving needs of users and ensure seamless connectivity in an increasingly digital world.

B. Latency: Exploring how real-time applications are impact by latency

Latency means delay in the transmission of data among devices over networks. In the context of real-time applications, such as video conferencing, online gaming, VoIP calls, and live streaming, latency can have a significant impact on user experience and application performance. According to [6], latency, which includes startup delays, rebuffering occurrences, as well as end-to-end delays is one of the critical variables that significantly influence user experience. This assertion was corroborated by research conducted by [7] to understand the end-to-end latency effect on a modern telecommunication network. In another study, [8] concluded that in the realm of modern computing, efficiency and speed are paramount, but these depend on latency as a critical factor for great user experience and system performance. The author indicated that latency, is also known as lag or delay in data transmission, response and processing helps to determine the seamlessness of the functions and interactions among various technologies**.** To determine the effect of latency on real-time application, some key points have been enumerated as follows:

1. **Communication Delay**: Latency introduces delays in the transmission of data packets, affecting the real-time applications such as VoIP calls and video conferencing. When latency is high, it could lead to audio/video desynchronization, choppy video playback, and communication lags.

2. **Gaming Performance:** In online gaming, latency, also known as ping, directly affects gameplay responsiveness and player interactions. High latency can result in delayed actions, laggy gameplay, and unfair advantages/disadvantages for players with different latency levels.

3. **Streaming Quality:** Latency can impact the quality of live streaming services by causing buffering, stuttering, and delays in content delivery. Viewers may experience interruptions in the stream or lower video/audio quality due to latency issues.

4. **Interactive Applications:** Real-time interactive applications, such as virtual classrooms, remote collaboration tools, and multiplayer games, require low latency to maintain smooth interactions between users. High latency can disrupt real-time collaboration and hinder user engagement.

5. **User Experience:** Latency directly influences the overall user experience of real-time applications. Users expect instant responses and seamless interactions in real-time communication and multimedia services. High latency can frustrate users and lead to a subpar experience.

6. **Network Conditions:** Latency can be influenced by various factors, including network congestion, packet loss, routing inefficiencies, and distance between devices. Optimizing network infrastructure and using low-latency networking technologies can help reduce latency and improve application performance.

7. **Quality of Service (QoS):** The implementation of good QoS techniques offers priority to real-time traffic which can help resolve the impact of latency on critical applications. QoS policies can ensure that real-time applications receive sufficient bandwidth and minimal latency for optimal performance.

8. **End-to-End Latency:** Real-time applications are sensitive to end-to-end latency, which includes data round time from source to destination and back. Minimizing end-to-end latency through efficient network design, routing optimization, and low-latency protocols is essential for real-time application performance.

In conclusion, latency is critical in network performance, responsiveness, and user experience of real-time applications. Network operators, application developers, and users need to be aware of latency issues and implement strategies to minimize latency for seamless real-time communication and collaboration.

C. Packet Loss and Jitter: Analysis of the effects of jitter and packet loss during data transmission

Jitter and packet loss are common network issues that can impact data transmission in real-time applications. A study to analyze the negative effect of packet loss on video quality was conducted by [9] using dataset containing 11,200 full HD and ultra-HD video sequences encoded to H.264 and H.265 format with packet loss rate (PLR) between 0 and 1%. Analysis of the simulation revealed that the quality of video declined as packet loss rate increases, irrespective of compression parameters. [10] determined that the measurement and analysis of jitter is critical to stable and reliable network connectivity, especially for real-time applications. The researchers contend that addressing the root causes of jitter offers the best opportunity for mobile network operators (MNOs) to optimize network performance, leading to enhanced user experience. Based on the reviews espoused, it can be concluded that packet loss and jitter have enormous impact on data transmission:

1. Packet Loss: This is the failure of network to deliver data packets to the destination. This can lead to gaps in transmitted data, affecting the integrity and completeness of the information being sent. In real-time applications, the loss in packets may lead to missing or corrupted data, leading to audio and video distortions, choppy playback, and communication disruptions. Aside also triggering retransmission requests, causing delays and increasing latency in data transmission, high packet loss rates can degrade overall application performance and QoS in real-time tools such as online gaming and video conferencing.

2. Jitter: Jitter refers to the variation in packet arrival times at the destination, causing irregular delays in data transmission. Jitter can be caused by network congestion, routing changes, or varying latency levels. Jitter can disrupt the smooth flow of data in real-time applications, leading to inconsistent playback, out-of-sync audio/video, and jittery performance. During VoIP calls and video conferencing, jitter can create call quality issues, including voice distortion, echo, and communication delays. Additionally, applications sensitive to timing and synchronization, such as live streaming and interactive games, may experience jitter-induced disruptions in data delivery.

3. Mitigation Strategies: To resolve these challenges, Forward Error Correction (FEC) techniques can be deployed to recover lost packets by providing backup data to packets under transmission, and regenerate packets at the

destination. This can help mitigate the effects of jitter through the reconstruction of the original data stream. Also, implementing buffer mechanisms can smooth out variations in packet arrival times caused by jitter, reducing the impact on real-time applications. Finally, prioritizing real-time traffic and ensuring sufficient bandwidth for critical applications can help minimize the effects of packet loss and jitter on data transmission, resulting in enhanced quality of service (QoS).

Analysis of this section shows that packet loss and jitter can significantly impact data transmission in real-time applications, leading to degraded performance, quality issues, and disruptions in communication. Understanding these network issues and implementing appropriate mitigation strategies are crucial for maintaining a reliable and seamless data transmission experience in real-time scenarios.

D. Throughput: Measuring the overall capacity and efficiency of data transfer

Throughput is a critical metric used to measure the overall capacity and efficiency of data transfer in a network or communication system. High throughput represents large amount of data transmission per second in a network, which offers fulfilment for user requests and overall healthy performance. On the other hand, low throughput means a network is delivering small data amounts per second, which leads to poor network performance caused by high latency rates, jitter and packet loss [11]. Throughput can be defined as the rate at which data is successfully transmitted from a source to a destination over a communication channel or network. It is typically expressed in bits per second (bps), kilobits per second (Kbps), megabits per second (Mbps), or gigabits per second (Gbps). It provides insights into the actual data transfer performance of a network or system, reflecting its capacity to handle and deliver data efficiently. While its measurement helps to assess the effectiveness of network infrastructure, understanding throughput enables network administrators and engineers to optimize network resources, identify bottlenecks, and improve overall data transfer speeds and reliability. Factors affecting throughput are; bandwidth, latency, packet loss, jitter, as well as protocol overhead. The measurement of throughput can be achieved using network performance testing software or by calculation, and can be improved through optimization, hardware upgrade, and implementation of QoS policies [11]. Throughput plays a crucial role in evaluating the performance and efficiency of data transfer in networks. Monitoring and optimizing throughput are essential for ensuring reliable and high-speed data transmission, meeting the demands of modern communication systems and applications.

E. Network Congestion: Addressing the challenges posed by network congestion

Network congestion occurs when the demand for network resources exceeds the available capacity, leading to performance degradation, delays, packet loss, and reduced throughput. Addressing network congestion is crucial to maintaining optimal network performance and ensuring efficient data transfer. A case study conducted with data set from Seoul city proves that rapid urbanization is causing network congestion levels to surge drastically, resulting in a direct impact on the quality the environment, urban life and the economy [12]. To resolve the congestion issues, the authors deployed Traffic Congestion Pattern Analysis and Convolutional Autoencoder to identify network paths that suffer from recurring congestion in performance prediction and mitigation in high traffic networks. Also, a report generated by [13] reveals that new network interconnections, system and dispatch changes, and resource retirement are responsible for the ever-increasing congestion in existing networks. The report further indicated that [13] used existing planning processes such as retirement, reliability, economics, and generation interconnection to remedy the adverse impact on the network transmissions. Internet of Things (IoT) consists of different computing devices operating on non-standard platforms typically have restricted bandwidth, limited storage capacity, and lower computing power tend to cause serious congestion in a network [14]. The paper concluded that, it is important to design a congestion control mechanism in order to facilitate efficient rates of data transfer within IoT networks. It is worth noting that network traffic management, capacity planning, load balancing, packet prioritization, congestion control algorithm, and monitoring and analysis are key strategies for resolving challenges associated with network congestion.

III. EMERGING TECHNOLOGIES AND NETWORK PERFORMANCE

A. 5G Technology: Assessing the implications of 5G on network performance

The drastic digital transformation currently taking place in society due to the advent of 5G has provided the internet with good things including the prospects of connecting 28 billion devices by 2025. The increased traffic volumes are largely met by the connectivity requirement of 5G, which includes low latency, high data rates, and high reliability. Despite this development, there exist some challenges that affect its application in the manufacturing industry [15]. With the use of the TOPSIS method which ensures robust results, the paper determined that 5G will positively impact on productivity, maintenance, flexibility, but little on network performance. The evolution of 5G technology has significantly introduced a shift in the telecommunication sector, offering unique opportunities and challenges. The new technology offers infrastructure upgrade and a shift in business models. However, the deployment and management of 5G also pose special challenges to mobile network operators (MNOs). According to [16], explored these unique challenges and determine 5G heightens network complexity, increases data volumes, and security and reliability issues. The rest are regulatory and standards compliance as well as the management of spectrum. To overcome these network challenges introduced by 5G, the author recommended Network Management Systems (NMS). The system would provide the needed solution through dynamic slice management, real-time analytics, configuration tools, and dynamic service management. Others are, security policy enforcement and precision time protocol (PTP) management [17]. Emerging technologies such as 5G has a great potential in the area of faster speeds (up to 10 Gbps), lower latency, increased capacity that supports large number of devices, enhanced reliability, and improved coverage. As this technology continues to roll out globally, it is expected to drive innovation and enable new applications that were previously not possible with current network technologies.

B. Internet of Things (IoT): Examining IoT's influence on network performance requirements

The Internet of Things (IoT) refers to the network of interconnected devices that communicate and share data with each other over the internet. As IoT devices continue to proliferate across various industries and applications, they have a significant impact on network performance requirements. A study conducted by [18] came to the conclusion that a typical IoT implementation has negative consequences on mobile network. It is believed that IoT introduces interference in wireless applications, reducing the efficiency and reliability of the network. The paper identified that, with the application of optimization and performance techniques, the challenges created by interference can be mitigated. The authors are clear about the fact that IoT devices create interferences that lead to that hurt the adequate functioning of business processes. The productivity issues, downtime challenges and customer satisfaction difficulties can be resolved by also deploying network convergence. An assertion was made by [19] to the effect that the adoption of IoT offers many advantages to organizations across the globe, yet it has the ability to also introduce unforeseen risks that needs the special attention of these organizations. To offset these risks and make sure IoT fits into its purposes the paper suggests changes to the organization, its processes and systems, as well as development of its capacity and capabilities. IoT has been identified as a phenomenon with a high negative impact on telecommunications network traffic. The exponential expansion in device connectivity causes significant rise in network traffic. A surge in network traffic may result in network congestion, which negatively affects network performance and user experience [20]. Additionally, connected IoT devices tend to generate and transmit big data in real-time, further straining the network and preventing from handling data flow in a fast-paced manner. Also, the sheer connection of the number of devices and the data generated necessitates higher bandwidth capacity or more operational cost. Overall, the increasing adoption of IoT devices underscores the importance of robust network infrastructure that can meet the evolving performance requirements of these interconnected devices. Network scalability, low latency, reliability, security, bandwidth management, and edge computing are key factors that organizations need to consider when designing and implementing networks to support IoT applications effectively.

C. Cloud Computing: Understanding the impact of cloud-based services on network performance

Cloud computing refers to the delivery of computing services, including storage, processing power, and applications, over the internet. Cloud-based services have revolutionized the way businesses and individuals' access and manage data, applications, and resources. Findings from an investigation conducted by [21] reveals that migrating an application to the cloud improves the performance of the application and reduces the energy consumption of the existing network. [22] opined that the adoption of cloud computing has the capacity to increase network performance through reliability and availability, reduced bandwidth requirements, and reduced network latency. The adoption of cloud computing has significant consequences on network performance due to increased data traffic, reliability and

availability issues, bandwidth requirements, and security concerns. The rest are network latency, scalability and flexibility challenges, and hybrid cloud environments. Organizations must prioritize network optimization strategies and invest in technologies that enhance network performance to maximize the benefits of cloud services while minimizing potential challenges.

IV. MEASUREMENT AND MONITORING OF NETWORK PERFORMANCE

A. Metrics for Evaluating Network Performance: Throughput, Response Time, Error Rate

Throughput measures the amount of data that can be transmitted over a network in a given period of time. It is typically measured in bits per second (bps) or packets per second (pps). Higher throughput indicates a more efficient network. Network performance metrics offer a deeper understanding for network infrastructure and the services under operation. The metrics have the propensity to offer real-time cursory view of the potential outages, challenges, and network errors. [23] has outlined some key network performance metrics capable of determining unexpected network challenges quickly. They include, bandwidth usage, pocket loss, retransmission, throughput, and latency. The rest are, network availability, connectivity and jitter. By regularly monitoring these metrics and analyzing performance data, organizations can identify potential issues, optimize network configurations, and ensure reliable and efficient network performance. Response time, also known as latency, measures the time it takes for a request to be sent from a client to a server and for the response to be received back. Lower response time indicates faster network performance and better user experience. Error rate measures the frequency of errors or data loss that occur during data transmission over the network. A low error rate is desirable as it indicates reliable network performance. Other metrics that can be used to evaluate network performance are packet loss, jitter, network availability, bandwidth utilization, and network congestion.

B. Tools and methodologies for monitoring network performance

Network monitoring tools are advanced capabilities produced to ensure that networks function appropriately, while delivering uninterrupted services. [23] has identified some of the best methodologies needed for effective network monitoring. They include; Bandwidth utilization monitoring, Network traffic monitoring, Built-in reporting system, and Dynamic and intelligent network mapping. Other are; Automatic alerting, Remote administration, Flow-based monitoring and reporting, and Intuitive centralized dashboards. The rest are; Wireless network performance metrics monitoring, User experience monitoring, and Automatic recovery. The most appropriate monitoring tool for network device is directly correlated with the variety of factors like network size and complexity. Also, the required features, budget constraints and integration needs are important [24,25]. Some of the essential monitoring tools include, Nagios XI, Datadog, Lansweeper, and StarWinds [26]. There are several tools and methodologies available for monitoring network performance. Some popular tools and methodologies include, Network monitoring software, SNMP (Simple Network Management Protocol), NetFlow and sFlow, Packet analysis, Performance testing tools, Quality of Service

(QoS) monitoring, and Synthetic monitoring. By leveraging these tools and methodologies, organizations can effectively monitor network performance, detect issues proactively, and optimize network resources to ensure reliable and efficient operation.

C. Case studies on real-time network performance monitoring

[27] provided a case study where a company called Obkio conducted network performance monitoring using a team of telecommunication experts who are specialized in performance monitoring. The team of experts first identified the network performance metrics and KPIs, they then collected and analyzed these metrics and KPIs. Finally, the analyzed metrics and KPIs were deployed towards the improvement of the performance. Here are a few case studies to show the benefits and importance of real-time performance monitoring of networks:

1. Case Study: Company X improves network performance with SolarWinds Network Performance Monitor (NPM)

Company X, a global technology company, was experiencing network slowdowns and outages that were impacting employee productivity and customer satisfaction. To address these issues, Company X implemented SolarWinds Network Performance Monitor (NPM) to monitor their network infrastructure in real-time. By leveraging NPM's network monitoring capabilities, Company X identified and resolved performance challenges before they impacted user satisfaction [27]. The tool provided visibility into network traffic, device performance, and application behavior, allowing IT teams to quickly troubleshoot and optimize network configurations. Based on this, the company recorded an increased performance in its network, with reduced downtime, faster response times, and improved overall user experience. Real-time network monitoring with SolarWinds NPM helped Company X maintain a reliable and efficient network infrastructure to support their business operations.

2. Case Study: Healthcare provider enhances patient care with real-time network monitoring

A large healthcare provider was facing network performance issues that were affecting the delivery of critical patient care services. Slow application response times, network congestion, and intermittent connectivity problems were impacting the efficiency of healthcare professionals and patient outcomes. To address these challenges, the healthcare provider implemented a comprehensive real-time network monitoring solution that included tools like PRTG Network Monitor and Wireshark [27]. These tools allowed IT teams enhanced network traffic monitoring capabilities, identified bottlenecks, and conducted troubleshooting on performance issues in real-time. By leveraging real-time network monitoring, the healthcare provider was able to ensure reliable access to electronic health records (EHRs), medical imaging systems, and communication platforms for healthcare professionals. The improved network performance resulted in faster diagnosis, treatment, and care coordination, leading to better patient outcomes and enhanced quality of care.

3. Case Study: Retail chain optimizes network performance with NetFlow analysis

A leading retail chain with multiple locations across the country was experiencing network congestion and slow application performance that was impacting customer transactions and store operations. To address these issues, the retail chain implemented NetFlow analysis to monitor network traffic and identify performance bottlenecks. By analyzing NetFlow data using tools like SolarWinds NetFlow Traffic Analyzer, the retail chain was able to pinpoint bandwidth-intensive applications, identify peak traffic times, and optimize network configurations to improve performance. Real-time NetFlow monitoring helped IT teams proactively manage network resources, prioritize critical applications, and ensure seamless customer experiences. As a result of implementing NetFlow analysis for real-time network performance monitoring, the retail chain saw a significant improvement in network performance, with faster transaction processing, reduced downtime, and increased customer satisfaction. The retail chain was able to optimize their network infrastructure to support business growth and deliver exceptional customer service across all store location [27].

V. STRATEGIES FOR OPTIMIZING TELECOMMUNICATIONS NETWORK PERFORMANCE

A. Network Virtualization: Leveraging virtualization for enhanced performance and flexibility

In the fast-paced outlook in the IT infrastructure landscape and its attendant issues, network virtualization provides the best solution. Virtualization of existing networks consist of the creation of integrated virtual networks to enhance flexibility and efficiency of the network. This can be achieved through the maximization of resource utilization, scalability, cost savings, enhanced security, data recovery, application-centric approach, and hybrid integration [28]. Network management challenges have been occasioned by increased variety of network functionality in addition to proprietary devices. The resultant effect is network ossification which in turn reduces the quantum and quality of service provisioning. To mitigate these problems, [29] encourages the deployment of Network Function Virtualization (NFV) as a promising phenomenon which is able to decouple network functions from the existing dedicated hardware and software. Network virtualization is the process of creating virtual networks that are decoupled from physical network hardware, allowing for enhanced performance, flexibility, and efficiency. By leveraging virtualization technologies, organizations can optimize their network infrastructure to meet the growing needs for current workloads and modern applications. Overall, network virtualization offers organizations a flexible, scalable, and cost-effective solution to optimize their network infrastructure and deliver high-performance connectivity for modern applications and services in a more secured environment. By leveraging virtualization technologies, organizations can enhance their network capabilities, improve operational efficiency, and adapt to evolving business requirements in today's dynamic digital landscape [29].

B. Software-Defined Networking (SDN) and Network Function Virtualization (NFV)

Software Defined Networking **(**SDN**)** play functions such as load balancing, network maintenance, and adaptive routing are good applications for cloud computing and IoT technologies.

1.1.1 Network Function Virtualization (NFV), offers both commercial and many academic communities' solutions. Additionally, virtualization also reduces storage and electric power use [30]. [31] asserts that the role played by SDN and NFV is instrumental in the 5G network architecture, and are key ingredients to network security and management. These are two key technologies that perform a crucial role part in network virtualization and modernization of network infrastructure. While they are related concepts, they serve distinct purposes and offer unique benefits in optimizing network operations.

Software-Defined Networking (SDN): SDN is an architectural approach that separates the control plane from the data plane in networking devices, allowing for centralized control and programmability of network resources. In an SDN environment, network administrators can dynamically manage and configure network devices through a centralized controller, rather than individually configuring each device. SDN features include:

1. **Centralized Control:** SDN enables centralized management of network devices, allowing administrators to define and enforce network policies from a single point of control. This centralized control simplifies network configuration and enhances network visibility and monitoring.

2. **Programmability:** SDN provides programmable interfaces that allow administrators to automate network provisioning, configuration, and optimization tasks. By leveraging APIs and software-defined protocols, organizations can customize network behavior to meet specific application requirements.

3. **Agility and Flexibility:** SDN architecture promotes agility and flexibility by decoupling network control logic from underlying hardware, making it easier to adapt to changing network conditions and business needs. Organizations can quickly deploy new services, scale network resources, and respond to dynamic traffic patterns.

4. **Improved Performance:** SDN optimizes network performance by dynamically routing traffic based on real-time conditions and application requirements. By implementing intelligent traffic engineering and load balancing algorithms, organizations can enhance network efficiency and reduce latency.

NFV is an approach for virtualizing the functions and services of networks that were originally undertaken by dedicated tools and devices like load balancers, routers and firewalls. Through the virtualization of network functions, organizations can consolidate multiple services onto a common hardware platform, improving resource utilization and scalability. Its main features and benefits include:

1. **Cost Savings:** NFV helps organizations reduce capital and operational expenses by replacing expensive proprietary hardware appliances with virtualized software-based solutions. By running network functions on cloud or standard server infrastructure, guarantees cost savings for companies through hardware consolidation and resource optimization.

2. **Scalability:** NFV enables organizations to scale network functions up or down based on demand, without the need for physical hardware upgrades. By deploying virtualized network functions in a cloud environment, organizations can dynamically allocate resources to meet changing workload requirements.

3. **Service Agility**: NFV promotes service agility by accelerating the deployment of new network services and applications through software-based provisioning. Organizations can quickly launch new services, update configurations, and scale resources without the constraints of traditional hardware-based solutions.

4. **Enhanced Security:** NFV enhances security by isolating virtualized network functions from each other and applying security policies at the software level. Organizations can implement granular access controls, encryption, and threat detection mechanisms to protect against cyber threats and data breaches.

In summary, SDN and NFV are complementary technologies that enable organizations to modernize their network infrastructure, improve operational efficiency, and deliver innovative services to meet the demands of digital transformation. By adopting SDN and NFV principles, organizations can achieve greater flexibility, scalability, performance, and cost savings in managing their networks and supporting diverse applications and workload.

C. Quality of Service (QoS) implementation for prioritizing critical traffic

Quality of Service is very critical in modern networks, because it is a phenomenon that measures the performance metrics and improves the experience of end-users [32]. IoT devices and 5G applications introduce challenges on networks QoS should be implemented at all times to ensure that the network maintains acceptable levels of QoS at all times. To achieve this, the authors proposed the queuing mechanism topological symmetry to reduce delay, pocket loss ratio, and the over-provisioning of resources. QoS is referred to a set of tools used to manage and prioritize network traffic to ensure that critical applications and services receive the necessary bandwidth, latency, and reliability they require. Implementing QoS in a network environment involves configuring network devices to classify, prioritize, and manage traffic based on predefined policies and service level agreements (SLAs) [32]. Here are major key steps for implementing QoS to prioritize critical traffic:

1. **Traffic Classification**: This phenomenon identifies and classifies network traffic according to their needs and importance. This may include voice, video, data, real-time applications, and mission-critical services. Use classification mechanisms such as IP address, port numbers, protocols, or Deep Packet Inspection (DPI) to differentiate between traffic types.

2. **Define QoS Policies:** Establish QoS policies that define the priority levels, bandwidth allocations, latency requirements, and packet loss parameters for each class of traffic. Create service level agreements (SLAs) that outline the performance expectations for critical applications and services.

3. **Traffic Prioritization:** Assign appropriate priority levels to different classes of traffic based on their criticality and requirements. Typically, traffic is classified into multiple queues with different priority levels (e.g., high priority, medium priority, low priority). Use QoS mechanisms such as Differentiated Services Code Point (DSCP), Class of Service (CoS), or Traffic Class to mark packets with the appropriate priority.

4. **Traffic Shaping and Policing**: Traffic shaping helps to control traffic transmission rate and prevents congestion by smoothing out bursts of traffic. Configure traffic policing to enforce traffic limits and ensure that non-critical traffic does not exceed allocated bandwidth, thus protecting critical applications from being starved of resources.

5. **Queue Management:** Configure queuing mechanisms such as First-In-First-Out (FIFO), Priority Queuing, Weighted Fair Queuing (WFQ), or Class-Based Queuing (CBQ) to manage the order in which packets are transmitted based on their priority levels. Implement scheduling algorithms to ensure that high-priority traffic is processed ahead of lower-priority traffic during periods of congestion.

6. **Monitoring and Optimization**: Continuously monitor network performance, QoS metrics, and compliance with SLAs to identify bottlenecks, latency issues, or packet loss. Fine-tune QoS policies and configurations based on real-time network conditions and feedback from users to optimize the prioritization of critical traffic.

By following these steps and leveraging QoS mechanisms, companies are able to prioritize critical traffic, attain consistent performance for essential applications, and enhance the overall quality of service delivered across their network infrastructure.

VI. ANALYSIS

This section analysis the information gleaned from the experimental data collected.

Fig. 1: Monitoring of Latency and MOS (*Adopted from Obkio's Dashboard, 2022)*

Fig. 1 depicts the monitoring graphs for latency and MOS using the best tools. The top left is monitoring conducted on Azure teams using "Your Agent" and shows that both the average and maximum latencies read 16.86ms, while the packet loss was 3.28%. Monitoring of the Google network with the same tool shows in the top left that average and maximum latency are the same at 16.82ms, but the packet loss was 4.03%. In the lower left and lower right graphs, the average and minimum MOS are 3.92/3.92 and 3.13/3.13 respectively.

Fig. 2: Monitoring of Latency and MOS (*Adopted from Obkio's Dashboard, 2022*

In Fig. 2, the metrics latency ad MOS were monitored over a period of 60secs. On the top left side of Figure shows the use of SD-WAN Firewall to WAN1 on November 2, 2022 at 3:00pm and the results were 9.94Mbps average latency and the same result for the maximum latency for incoming traffic, and 1.01Mbps each for the outgoing traffic. On the same date at 12:20pm, SD-WAN Firewall was used to monitor WAN2 and it revealed that both the average and maximum latency were 567.31Mbps for inbound traffic and outbound were 9.85Mbps for both average and maximum latency. However, during these two monitoring exercises, no errors were recorded. This is an indication that networks behave differently at different times and should be monitored always to detect any discrepancies.

Even in the absence of errors, WAN two had higher latency both at the in incoming and outgoing traffic compared to WA1.

On the other hand, 'Your Agent' was used to monitor Google and Azure Teams on the same date and time as depicted on both the bottom left and right of Fig. 2. The Mean Opinion Score (MOS) was monitored in both cases, the left side had 4.1 for both average and minimum records, while right hand side recorded 4.17 for both average and minimum opinions. This is a clear manifestation of the fact that each network has different opinions generated by users, and it is through monitoring that these can be detected.

Fig. 3: Monitoring of DNS, TCP SSL and Others. (*Adopted from Obkio's Dashboard, 2022)*

On the upper left of Fig. 3, 'You Agent' tool was used to monitored Google network on November 2, 2022 at 12:20:14pm, and the outcome indicates that the Domain Name System (DNS) recorded 86.90ms, Transmission Control Protocol (TCP) had 12.00ms, Secure Sockets Layer (SSL) was 261.70ms and the WAIT time for the CPU was 110.90ms. On the same date, at 12:20:08 pm, the SD-WAN Firewall was used to monitor the utilization of four CPUs with 60 seconds, and results show that, CPU1, CPU2, CPU3 and CPU4 were utilized 10%, 7%, 15% and 13% respectively. Utilization of the CPU measures the amount of traffic on the network, and for the four CPUs the figures were relatively small, indicating the network is very healthy. The bottom left of Fig. 3 measured average and maximum latency as 14.26ms and 14.61ms respectively. The jitter was 2.92ms, while packet loss was 6.03%. On bottom right, both average and maximum latency were 15.11ms, jitter was 3.25 and packet loss 4.27%. These results show a healthy network with efficient performance.

TABLE I: THE IMPACT OF CALL QUALITY ON MEAN OPINION SCORE (MOS)

No.	Call Quality	MOS
1	Best	over 4.34
2	High	4.03-4.34
3	Medium	3.6-4.03
4	Low	3.1-3.6
5	Poor	below 3.1

1.1.2

Table I illustrates the effect of call quality on the average number of opinions (MOS) or commendations from network users. When opinions formed about the network is more 4.34, it means the quality of call is the best. High quality of calls generates 4.03-4.34 MOS, medium quality is 3.6 to 4.03 up to poor call quality represented by MOS below 3.1. Comparing Table 1 with results from Fig. 2 reveals that the call quality of the network monitored is high.

A. Contributions of the Study

Per the results or findings made in section VI of the study, the contributions include:

1. Network Architecture Improvements: Analyzing different network architectures (e.g., SDN, NFV) that can enhance performance, scalability, and flexibility of telecoms networks.

2. Traffic Management Techniques: Discussing algorithms and techniques for effective traffic management, including Quality of Service (QoS) mechanisms, load balancing, and congestion control.

3. Performance Metrics: Identifying key performance indicators (KPIs) used to measure network performance, such as latency, throughput, jitter, and packet loss.

4. Data Analytics and AI: Exploring the role of big data analytics and artificial intelligence in predicting network behavior, identifying bottlenecks, and automating network optimization processes.

5. Resource Allocation Strategies: Examining resource allocation strategies that optimize bandwidth usage and improve overall network efficiency.

6. Energy Efficiency: Discussing methods to reduce energy consumption in telecommunications networks while maintaining performance levels, contributing to sustainability goals.

7. Emerging Technologies: Reviewing the impact of emerging technologies such as 5G, IoT, and edge computing on network performance optimization.

8. Security Considerations: Addressing how optimizing network performance can be balanced with security measures to protect against vulnerabilities and attacks.

9. Case Studies and Real-World Applications: Providing insights from case studies that illustrate successful optimization strategies implemented in various telecommunications settings.

VII. RECOMMENDATIONS FOR TELECOM OPERATORS AND ORGANIZATIONS

This section seeks to offer some recommendations to mobile network operators (MNOs) and organization to help them optimize their networks for efficient performance and customer satisfaction.

A. Best Practices for Maintaining high Network Performance

Maintaining high network performance is essential for ensuring optimal user experience, productivity, and efficiency within an organization. To achieve this, MNOs and organizations should implement regular monitoring and analysis, conduct regular capacity planning, implement network segmentation to divide the network into logical segments or VLANs based on departments, applications, or security requirements. Also, QoS should be implemented along with network optimization and the design of a robust security system including intrusion detection and prevention and firewalls. Finally, redundancy mechanisms such as link aggregation (LACP), failover configurations, redundant power supplies, and backup connections to ensure high availability and minimize downtime, and regular maintenance and updates should be conducted.

B. Investment considerations for network performance optimization

Investing in network performance optimization is a critical ingredient for improving network efficiency, productivity, and high user satisfaction. Some of the key investment considerations for optimizing network performance include, network infrastructure upgrades, bandwidth expansion, network monitoring tools, QoS solutions implementation, and network segmentation technologies. Additionally, investments should be made for network security solutions, redundancy and high availability, and training and skills development.

C. Future trends and challenges in telecommunications network performance

Future trends and challenges in telecommunications network performance are influenced by technological advancements, evolving user demands, and the increasing complexity of network infrastructures. It is recommended that the following key trends and challenges are considered, 5G network rollout, Internet of Things (IoT) expansion, edge computing integration, Virtualization and Software-Defined Networking (SDN), and resolving network security Concerns. In addition, Quality of Experience (QoE) optimization, network automation and AI, as well as sustainability and green networking should be implemented.

VIII. CONCLUSION

This study has provided a comprehensive review and analysis of the various strategies and technologies employed to optimize telecommunications network performance in an increasingly complex and demanding environment. The rapid growth of mobile devices, IoT applications, and high-bandwidth services poses significant challenges for network operators, necessitating innovative solutions to ensure efficiency, reliability, and quality of service. The findings highlight that a multi-faceted approach is essential for effective network optimization. Techniques such as traffic management, resource allocation, and quality of service enhancements are critical in addressing immediate performance issues. However, the integration of advanced technologies like Artificial Intelligence (AI) and Machine Learning (ML) is pivotal for enabling predictive analytics and dynamic network management. These technologies empower operators to anticipate network demands and make informed decisions that enhance overall performance. Moreover, the adoption of Software-Defined Networking (SDN) and Network Function Virtualization (NFV) has emerged as transformative strategies that allow for greater flexibility and scalability in network architectures. These innovations enable operators to respond swiftly to changing conditions and user demands, fostering a more resilient telecommunications infrastructure. The role of big data analytics cannot be overstated, as it provides valuable insights into user behavior and traffic patterns. By leveraging this data, network operators can optimize planning and resource allocation, leading to improved service delivery and customer satisfaction.

Additionally, addressing security concerns remains paramount in the optimization process, as robust protocols are essential to protect network integrity and user privacy in the face of evolving cyber threats. The research contributes to the existing literature by synthesizing current knowledge and identifying best practices, ultimately offering a roadmap for future innovations in telecommunications network performance enhancement. Recommendations for further research are provided, focusing on emerging technologies and user-centric models to ensure sustainable and efficient telecommunications infrastructures in the digital era. Some areas include:

- Investigate the implications of network slicing for performance optimization in 5G networks, including case studies on its implementation across different industries.
- Examine optimization strategies tailored for rural or underserved areas, considering the unique challenges and resource constraints faced by these networks
- Explore the potential of blockchain technology to enhance security and trust within telecommunications networks, particularly in the context of optimization.
- Investigate how collaboration between telecommunications providers and other industries (e.g., healthcare, transportation) can lead to innovative optimization solutions that benefit multiple sectors.

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ARTICLE 5

Review On Vertical Handover Techniques in VANET: Algorithms, Input Parameters, and Evaluation Metrics

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***Abstract*— Vertical Handover Techniques (VHOs) allow mobile devices that support multiple wireless technologies to switch from one wireless network to another by promising to maintain a seamless connection in highly dynamic scenarios such as in-vehicle networks (VNs). Persistent connectivity is a serious problem caused by the extremely dynamic network topology and the highly variable number of nodes being moved. In addition, the efficiency of traffic and the effectiveness of the dissemination of road safety messages is a serious problem. Recently, heterogeneous cellular networks with DSRC for the automotive network have been proposed and have attracted a lot of attention. The consolidation offers many possible advantages, such as high data rates, low latency, and extended communication range. In a heterogeneous wireless environment, a smooth handover decision is required to ensure the QoS of communication and maintenance of continuous connection between mobile nodes. This article reviews some relevant studies (algorithms, input parameters, and evaluation metrics) in the literature dealing with VANETs and other heterogeneous wireless communication networks in terms of vertical handover technology. In addition, this work will aid future researchers in gaining insight into the collaboration of vehicular heterogeneous networks (especially DSRC and Cellular Networks) in constructing VANETs and improving driver safety.**

KEYWORDS

Vertical Handover, Heterogeneous Vehicular Communication, DSRC, Cellular Networks

Introduction

The growing communication infrastructure allows connections through a variety of wired and wireless technologies in different settings. The adoption of wireless technology is growing at a very rapid rate. This trend is essentially due to reasons such as (i) the miniaturization of devices such as laptops, and netbooks, (ii) the multiple networking interfaces available in most devices, and (iii) the availability of several wireless technologies such as Wireless Fidelity (Wi-Fi), Worldwide interoperability for Microwave Access (WiMAX), and Universal Mobile Telecommunications System (UMTS), Long Term Evolution (LTE) and 5G. The need to integrate different wireless network technologies to provide "seamless" interoperability, integration, and convergence between these heterogeneous technologies necessitates the use of Vertical Handoff (VHO) technology.

Handover, also known as handoff, is an event that occurs whenever a mobile node moves from one radio cell to another, giving up its connection with the first base station and connecting to the second base station. When a handover occurs within the realm of a single radio access technology, the process is called horizontal handover. On the other hand, vertical handover is a term meaning handover between heterogeneous radio access network technologies. Fig. 1 shows both horizontal and vertical handover events. Handoff technology has been extensively studied in cellular communications and is gaining attraction in IP-based wireless networks [1]. A handover is considered 'smooth' when all applications running on the mobile device can keep the connection alive, providing continuous end-to-end data service within the same session during the switchover, providing both low latency and minimal packets. Loss.

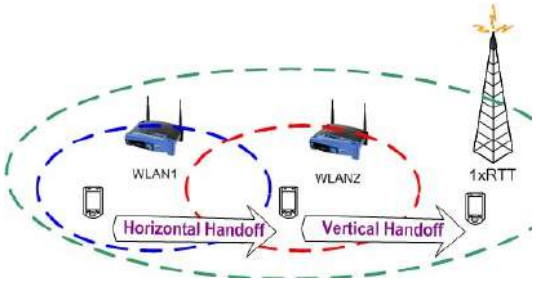

Fig. 1: Illustration of the horizontal and vertical handover processes

The research community is putting considerable effort into the convergence of various wireless networking technologies. Because of this, there are various proposals covering heterogeneous scenarios, protocols, handover techniques and algorithms, network technologies, metrics, and procedures. In addition, the IEEE 802.21 working group, which aims to provide a homogeneous functional interface between heterogeneous network technologies, has been working on the Media Independent Handover Services Protocol, [2] since 2004 to provide standard handover services between lower and upper layers. In November 2008, the IEEE 802.21 standard was finally approved. Nevertheless, there have been proposals and studies to improve and solve the performance of 802.21 in terms of VHO efficiency. [3], [4], [5].

Regarding standards, VHO techniques, algorithms, input parameters, and evaluation metrics, this review intends to review the most important proposals found in the literature. It also highlights the VHO process from a heterogeneous vehicle network (VN) perspective, highlighting techniques and algorithms that are better suited for this type of network. As most of the proposals in the literature merely consider specific VHO techniques for heterogeneous vehicle networks this review paper may be useful for this purpose.

2. Vehicular Networks

Every year, millions of people die in road traffic accidents around the world. About 1.25 million people die each year as a result of road traffic accidents (3400 deaths per day) [6] according to the World Health Organization (WHO) review on road traffic injuries (May 9, 2016). Furthermore, forecasts predict worse conditions by 2020 and estimate that road traffic accidents will increase to become the seventh leading cause of death [7]. Preventing these accidents by

Clearly articulating this prediction has been a challenge. Urgent action and focused efforts are required to prevent and reduce vehicle accidents and improve road safety.

Intelligent Transportation Systems (ITS) have recently attracted academia and industry to save lives, money, time, and the environment. Japan and Sweden have publicly announced the goal of a zero-traffic fatality society by 2020 and beyond, hoping for such technologies (ITS) [8]. The Intelligent Transportation Association (ITSA)'s "Vision Zero" manifesto summarizes its mission to minimize fatal accidents and delays [9]. With the recent development of the automobile and wireless communication technology, the development of ITS solves many vehicle traffic problems, such as information dissemination and traffic congestion. One component of ITS for mobile vehicle connectivity and wireless communications is the Vehicle Ad-hoc Network (VANET). Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communications in VANET are inherently enabled by wireless communication technologies. A process by which vehicles can communicate with each other and exchange information about their status (e.g. position, speed, acceleration, etc.) or traffic information (e.g. traffic light status, accidents, traffic jams, a line running, etc.) is called V2V communication.

V2I communication refers to the collaboration between road infrastructure and automobiles in a similar operation. VANETs handle both safety-critical applications and non-safety infotainment or entertainment-based applications. Safety applications such as collision avoidance, pre-crash awareness, or lane change are used to reduce road accidents by employing traffic monitoring and management apps. Non-safety applications are used to allow passengers to access various services such as interactive communication, internet access, payment services, online games, and information updates while cars are in motion.

The IEEE 802.11p standard [10, 11, 12] is an update to the well-known IEEE 802.11 standard that is based on considerable VANET research. The upgraded version of IEEE 802.11p is the standard for Wireless Access in Vehicular Environments (WAVE) with a frequency of 5.9 GHz. The WAVE protocols (IEEE 802.11p/1609) enables interoperability between wireless devices on-board units (OBU) of cars and infrastructure located near the roadside unit (RSU). Thus, V2V and V2I connections may be formed in the vehicular network. Despite the substantial study, IEEE 802.11p suffers from scalability concerns, restricted coverage areas, and unbounded delays.

Cellular networks, on the other hand, have recently been incorporated. Due to several difficulties associated with IEEE 802.11p, researchers have been driven to study the feasibility of utilizing cellular networks in-vehicle applications instead of IEEE 802.11p. By comparing the features of various access methods, it is established that the cellular network is the best alternative to IEEE 802.11p for supporting vehicle applications. LTE's distinctive properties are fast data rates, good spectral efficiency, and reduced control plane latency [13]. Existing radio access networks, such as cellular networks (3G/LTE/5G) and Wi-Fi, may be used to improve vehicular communications and guarantee cars have access to the network even when RSUs are not present. The potential impact of heterogeneous wireless networks has proven that the ever-increasing volume of mobile internet traffic cannot be absorbed entirely by cellular data communication networks. A heterogeneous vehicular network can be formed by combining VANETs with cellular networks for automotive communications.

When migrating between heterogeneous networks, flawless handover is the initial step. It is more critical to initiate vertical handover for convenience reasons than for connection purposes (e.g., according to user choice for a specific service). Vertical handover management has two significant challenges: seamlessness and automation in network switching. The growing relevance of interconnectivity across VANETs has been acknowledged by major automobile manufacturers, governmental bodies, and the academic community [14]. Many government initiatives have been carried out in the United States, Japan, and the European Union. The Federal Communications Commission has awarded spectrum to Inter-Vehicle Communications (IVC) and comparable applications [15].

Governments and well-known industrial companies such as Toyota, BMW, and DaimlerChrysler have initiated important projects for IVC communications. The following are several noteworthy projects from the Japan Automotive Research Institute (JSK) that are an important step towards realizing intelligent transportation services; Advanced Driver Assistance Systems (ADASE2) [16], Collision Avoidance Metrics Partnership (CAMP) [17], Chauffeur in EU [18], CarTALK2000 [19], FleetNet [20], California Partners for Advanced Transit and Highways (California PATH) [21], and DEMO 2000.
In recent years, few studies have investigated heterogeneous vehicle communication. An overview of a single network or ITS is the focus of these existing investigations [13], [22, 23, 24, 25, 26]. Wu et al. [27] address the challenge of using dedicated short-range communications (DSRC) for vehicle communication and proposed solutions. [28] provided a comprehensive overview of automotive ad hoc networks. Problems and solutions to connected vehicles were discussed by the authors in [29]. Each system offers its unique advantages, so heterogeneity between different networks is important [30]. Viriyasitavat et al. [31] analyzed the appropriate channel and propagation models for this heterogeneous system because the automotive network environment is very dynamic. Various automotive applications have also been considered in some studies[32, 33, 34]. Furthermore, the ability of LTE to support vehicular applications is briefly evaluated in [13]. On the other hand, the coverage problem in VANETs [35] is proposed as a solution together with the Worldwide Interoperability for Microwave Access (WiMAX) network. Studies in [13] and [23] focus on the use of LTE in vehicular networks over heterogeneous wireless networks.
3GPP LTE and IEEE 802.11p/WAVE technologies were compared by Vinel et al to determine which technologies can support collaborative media security applications [23]. Basic techniques and principles of Internet access in VANETInternet integration scenarios have been studied by Mane & Junnarkar in [36]. To prioritize the dissemination of urgent messages, they worked to improve the performance of mobile gateways and data collection. Furthermore, V2I communication over heterogeneous multilayers with multiple Radio Access Technology (RAT) network environments is reviewed in [24]. The various VANET technologies in the survey were presented by Shahid et al. in [37]; while for vehicle safety at intersections, UMTS and LTE were compared in [38]. In addition, Mir et al. compared a hybrid communication system between LTE and WAVE protocols [39]. In contrast, for heterogeneous vehicle communications, a combination of both LTE and 802.11p as a hybrid approach has been proposed in [40]. Collaborative efforts have been suggested in [41, 42, 43] different LTE-VANETs. DSRC for V2V communication and LTE for V2I communication is one of the best solutions to support vehicular services in the heterogeneous vehicular network as concluded in a study [44] by Zheng et al.

For our study, we present a review of vertical handoff techniques in the heterogeneous vehicular communications environment. Along with existing surveys in the literature, this current article focuses on comparing the different solutions provided by the VANET research community for vertical handover looking at the algorithms, input parameters, and

Evaluation metrics used. Metrics such as bandwidth, throughput, latency, communication overhead, channel capacity, and packet loss are the comparisons on which different operations are based. Many challenges must be addressed to make the vehicle communication idea a commercially sustainable reality for 5G networks and autonomous vehicles. This work will motivate VANET researchers, automakers, and new entrants to develop VANET heterogeneous wireless network integration technologies.

The rest of this paper is structured as follows. VANET architecture and background are discussed in Section 2. Wireless access standards in VANET are discussed in Section 3. VANET characteristics are briefly described in Section 4. Section 5 discusses heterogeneous vehicular communications possible scenarios. Section 6 discusses the various vertical handover stages, the Input Parameters, Evaluation Metrics, Algorithms, and Approaches used for Vertical Handover in literature.

2. VANET: Architecture

The special network in which the devices that make up the network is known as the Vehicle Adhoc Network (VANET). VANET is not the same as Intelligent Transportation System (ITS). All types of communication inside a vehicle, between vehicles, or with a road unit are under ITS. ITS is not only limited to road transport but also includes rail, maritime, and air transport. This means that VANET is a subset of ITS. As shown in Fig.2, there are three types of domains in the architecture of the VANET communication system: the in-vehicle domain, the ad-hoc domain, and the infrastructure domain.

2.1. In-Vehicle Domain

An onboard unit (OBU) and one or more application units (AU) are included in this domain. A single OBU can be integrated into multiple AUs; between them can be wired or wirelessly connected. The communication links between V2I and V2V are ensured by an OBU. Then, a single network device based on IEEE 802.11p radio technology is installed on an OBU.

2.2. Ad-hoc Domain

Vehicles prepared with OBUs and stations through the roadside, i.e. Road Side Units (RSUs) incorporate the Ad-hoc Domain. An RSU may be visible as a static node whilst an OBU may be visible as a movable node of an ad-hoc community. A gateway is required to connect the RSU to the World Wide Web. Directly or through multi-hops RSUs can talk with each other. Providing internet connectivity to the OBUs is the primary goal of the RSU. It also forms a mobile ad-hoc network that allows OBUs to communicate between vehicles without the need for centralized coordination. [45].

2.3. Infrastructural Domain

To access the infrastructure, the network RSU can connect the OBU to the Internet as shown in Fig. 2. This allows the AU through the OBU to connect to any Internet-based host. For non-safety applications, the OBU can also communicate with other hosts using cellular radio network communications (GSM, GPRS, UMTS, HSDPA, WiMAX, and 4G).

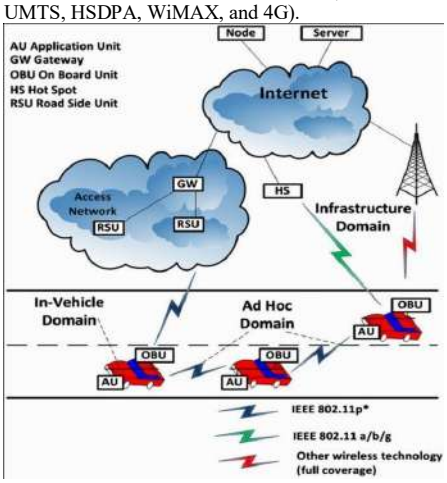

Fig. 2. The architecture of the VANET communication system.

The specific constituents of VANET are an application unit, an onboard unit, and a roadside unit. The architecture given below gives a momentary description.

A. On-Board Units (OBUs)

In addition, a vehicle using a permanently installed OBU exchanges information with the RSU or with other OBUs. For use in short-range wireless communication based on IEEE 802.11p radio technology, the OBU includes a resource control processor (RCP), a user interface, and a dedicated interface for connecting to other OBUs and network equipment. Additionally, for non-safety applications based on other radio technologies such as IEEE 802.11a/b/g/n, it may include an additional network device. Through a wireless link based on the IEEE 802.11p radio frequency channel, the OBU is

Responsible for communicating and connecting with the RSU or other OBUs. Wireless radio access, network congestion control, ad-hoc and geo-routing, reliable messaging, data security, and IP mobility are key roles of the OBU.

B. Application Units (AUs)

An integrated entity called the Application Unit (AU) works with the OBU and shares OBU processing and wireless resources. Similarly, multiple AUs can work with a single OBU and assume similar responsibilities. To manage all network utilities and mobility, the AU interacts exclusively through the OBU [45]. To connect to the OBU, the AU and OBU connections can be wired or wireless to the OBU in a single physical unit. In addition, for all mobility and network functions, the AU communicates with the network via the OBU.

C. Road-Side Units (RSUs)

The devices that are placed at static locations along roads and highways or specific locations such as intersections, near parking lots, hospitals, shopping malls, restaurants, etc. are referred to as a Road-Side Unit (RSU). They are composed of at least a network device based on IEEE 802.11p. The main function of the RSUs is to provide internet connectivity to the OBUs. A group of sensors with an OBU fitted on the vehicle will collect the information and send it to other vehicles or the RSU via wireless channels. As a bridge, RSU also connects multiple AUs of vehicles to the Internet [46]. The primary functions and procedures according to the Car 2 Car Communication Consortium [47], concerning RSUs are [28]:

- To redistribute the information to other OBUs and other RSUs to forward it to other OBUs by this there is an extension of the ad hoc network.
- To use V2I communication to run safety applications such as a low bridge warning, accident warning, or work zone, and also act as an information source.
- To provide the OBUs with an internet connection.

Allowing communication among nearby vehicles, between vehicles, and fixed roadside units is the main goal of the VANET architecture. This is shown in the following three categories as shown in Fig. 3.

a. Vehicle-to-Vehicle (V2V) Communication

V2V communication allows direct vehicular communication without depending on fixed infrastructure support. This is also referred to as inter-vehicle communication. Safety, security, and dissemination applications are primarily featured in V2V. Moreover, for V2V communication, to expand the users' perceptual horizon the vehicles exchange data which can describe the vehicles' internal states and environment. In this way, any important information collected from the sensors on a vehicle may be sent to its neighbouring vehicles. Therefore, to prevent fatal road accidents V2V communication is necessary. It is mostly present in the form of automotive lighting, such as turn signals and brake lights.

b. Vehicle-to-Infrastructure (V2I) Communication

Communication between a vehicle and the roadside Infrastructure is responsible for the V2I communication for information and data-gathering applications. Cellular gateways and wireless space networks have used the vehicles. V2I communication for safety purposes is defined by the United States Department of Transportation (US DoT) as the wireless exchange of critical safety and operational data between vehicles and roadway infrastructure, intended primarily to avoid motor vehicle boom [48]. Providing information and entertainment services to drivers and passengers are the extra features that can benefit from the wireless exchange of data. Automotive information and entertainment services can be, current weather forecasts, traffic information, online gaming, music, and video streaming. To alter the duration of traffic light phases or to report traffic situations and the internal state of the vehicle, the vehicles can interact with infrastructure. For routing purposes, a VANET roadside infrastructure can be used.

c. Hybrid Architecture (V2X)

The working together of V2V and V2I communications in VANET form a hybrid architecture. For example, a vehicle can communicate with the roadside infrastructure and share the data received from the infrastructure with other vehicles. Two types of communications are available in the adhoc domain according to [49, 50, 51]. Vehicles can communicate directly with another vehicle if there exists a direct wireless connection available between them this is known as a single hop V2V communication on the other hand the condition exists differently when there is no direct connection between them. A dedicated routing protocol is used to forward data from one vehicle to another until it reaches the destination point this is also known as multi-hop V2V communication. The vehicles can also communicate.

With the RSU, the range of communication by receiving, sending, and forwarding data from one node to another V2I communication.

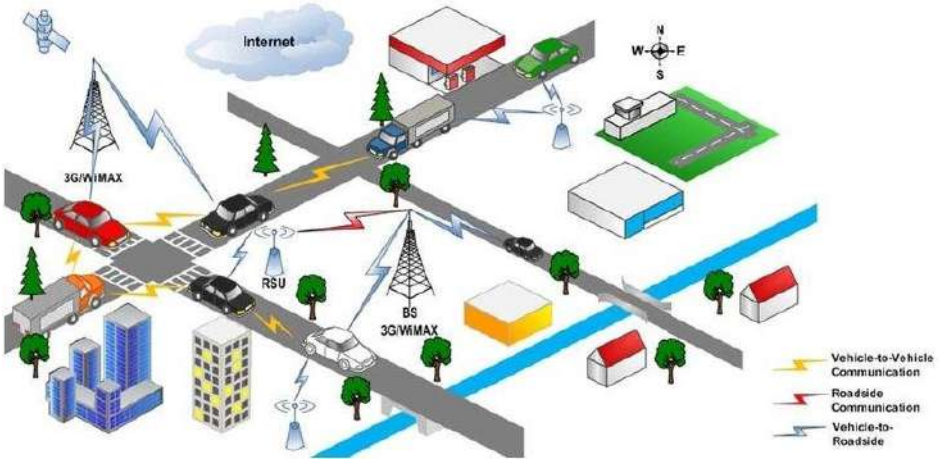

Fig. 3. Communication in VANET

3. Wireless Access Standards in VANET

Many technologies are utilized in VANET, including Dedicated Short-Range Communication (DSRC) and Wireless Access in Vehicular Environment (WAVE).

3.1. Dedicated Short-Range Communication (DSRC)

The United States Federal Communication Commission (FCC) assigned 75 MHz of the dedicated short-range communication (DSRC) spectrum at 5.9 GHz between 5.850 and 5.925 GHz for ITS in 1999 [52], [53] In 2008, the European Telecommunications Standards Institute (ETSI) granted 70 MHz of spectrum in the 5.8 GHz range [54] for DSRC applications. The ISO Communication Access for Land Mobiles (CALM) began DSRC standardization in 2001, and the IEEE 802.11p was concluded in 2010 [55]. In this day and age, the DSRC has emerged as the appropriate standard for V2V and V2I communications. The DSRC communication range is
300 meters to one kilometre, allowing for high-speed communication between automobiles and roadside infrastructure as well as between vehicles. It can withstand speeds of up to 200 km/h. Half-duplex with a transfer rate of 6-27 Mbps is the standard. The Orthogonal Frequency Division Multiplexing (OFDM) technology is supported by DSRC for data multiplexing. The OFDM approach divides the input data stream into parallel bitstreams and transfers the individual bitstreams onto overlapping subcarriers.

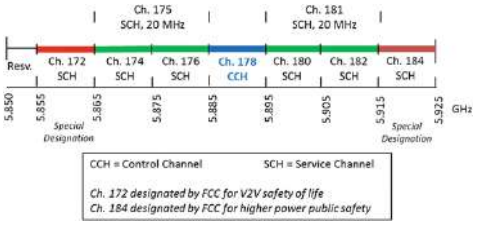

Fig. 4. DSRC spectrum is allocated by the FCC

The DSRC spectrum is divided into seven channels, as seen in Fig. 4 and 5, starting with channel number 172 and concluding with channel number 184. The spectrum consists of a 5 MHz guard band, one 10 MHz Control Channel (CCH), and six 10 MHz Service Channels (SCHs). Channel 178, the control channel (CCH), is used only for safety communications. Furthermore, channels 172 and 184 are allocated for safety purposes, while the remaining service channels are utilized for both safety and non-safety applications (SCH). According to the ETSI institute [56], the entire spectrum in DSRC is divided into time slots of 50 ms, with messages having two different priorities: low for data dissemination messages delivered in the SCH channels, and high for safety or control signals transmitted in the CCH channel. When the CCH channel is active, all nodes must cease communicating during the CCH time frame to receive and deliver security messages.

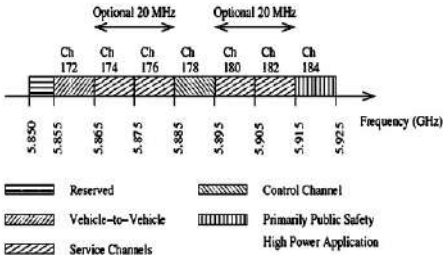

Fig. 5. Multi-channel operation in a vehicle network that complies with the IEEE802.11p European standard.

3.2. IEEE 1609-Standards for Wireless Access in Vehicular Environments (WAVE)

Wireless Access for Vehicular Environments is another name for IEEE 802.11p (WAVE). WAVE is an IEEE 802.11 standard modification. The WAVE standard is necessary for ITS applications in short-range communications. High-speed data transport and communication are essential due to the high topological change and mobility of Vehicular nodes. As a result, the ASTM 2313 working group rebranded DSRC to IEEE 802.11p WAVE [57]. This is possible on both the MAC and physical layers. WAVE includes the Road Side Unit (RSU) and On-Board Unit (OBU). WAVE uses the 5.850-5.925 GHz frequency spectrum for V2V and V2I communications. Using real-time traffic analytics can help enhance VANET performance. WAVE uses OFDM techniques to split the signals into different narrowband channels.

4. Characteristics of the VANET

The notion of vehicular ad-hoc networks (VANETs) evolved from mobile ad-hoc networks (MANETs). They share traits such as low bandwidth, short radio transmission range, self-organization, self-management, and omnidirectional broadcast. VANETs have various characteristics that set them apart from traditional mobile Adhoc networks.

VANETs have the following distinguishing features:

- *Highly dynamic mobility and topology:* A vehicular network is deemed highly dynamic due to the speed of the vehicles and radio propagation characteristics. As a result, automobiles travel at speeds ranging from 50 km/h in urban areas to more than 100 km/h on highways [58]. The dynamic nature of the vehicular network causes them to swiftly join or exit the network, resulting in irregular and rapid topology changes.

- *Network topology evolves quickly:* VANET nodes are known for their high speed. Vehicles on the road change their position and speed often, causing the network topology to vary rapidly. The duration of the link between vehicles is affected by the radio communication range and vehicle direction. Cars travelling in opposing directions may have a relatively short lifespan link, whereas vehicles travelling in the same direction may experience frequent link ruptures and more packet loss, resulting in lower throughput. When the link connection fluctuates rapidly and many pathways are severed before being used, the effective network diameter shrinks [59].

- *Low link availability (often disconnected):* When the network topology is very dynamic, with high-speed vehicular nodes and limited transmission range, the link between two cars can abruptly evaporate while transferring information. As a result, vehicles travelling in opposing directions and vehicles travelling in the same direction at high speeds may have low link availability.

- *Variable network density:* The network density in VANET fluctuates depending on the time and the network area. In suburban traffic, network density can be relatively low, while in a metropolitan traffic bottleneck, it can be very high. During rush hour, there is a lot of traffic, however, it is normally light in rural areas [60], [54].

- *No power constraints:* In the VANET, power is not a major issue because cars can deliver continuous power to the OBU due to their long battery life. In the case of mobile ad-hoc networks, this is not the case. [60, 61, 62].

- *Restricted and predictable mobility:* In-vehicle ad-hoc networks, nodes do not move at random; instead, they follow lanes and itineraries, which is not the case in mobile ad-hoc networks. Given the vehicle's mobility pattern, which is normally confined by roads, streets, highways, traffic signals, speed limits, and traffic conditions, it is more feasible to anticipate the vehicle's future position.

- *Huge-scale network::* Dense urban regions, such as city centres, major city entrances, and highways, may have large networks [60], [54]. As a result, identifying the intended receiver before data distribution becomes a major difficulty because VANET may encompass numerous towns or cities.

- *Hard delay limitations and real-time needs:* VANET protocols must meet the requirements of applications. Safety messages are the prime purpose of VANETs.

As a result, safety messages must be specified of top importance and delivered on time.

- *Geographical communication:* Where cars can be accessed is determined by their geographic position. The situation is different in other networks where an ID or a group ID defines the target vehicle or a group of target cars.

- *Urban versus Rural:* Vehicle density varies across time and place, which is a significant difficulty. In rural locations, network dispersion and increased interference, respectively, make V2V communication difficult and contribute to shadowing and fading in urban circumstances.

- *Propagation model:* VANETs can operate in three different environments: highway, rural, and urban. In a highway, the propagation model is usually believed to be free space. The signal is reflected in the signal by the wall panels around the roads, causing interference. Because of the varying vehicular density and the existence of buildings, trees, and other objects that interfere with signal propagation, the surroundings in a city make communication problematic. The impacts of such opposition include shadowing, multipath, and fading. The propagation model is generally believed not to be free-space due to the features of the communication environment. Due to the various topography shapes, it is critical to address signal reflection and attenuation during signal propagation (fields, hills, climbs, dense forests, etc.). As a result, the free-space paradigm is inappropriate in this case. The impacts of potential wireless communication interference from other vehicles and networks must be included in the VANET propagation model.

- *High computational ability:* VANET nodes can be supplied with a sufficient number of sensors and computing resources, such as CPUs and big memory capacity, to boost their computational capability. This will aid in the establishment of secure wireless communication. Furthermore, these resources will be quite useful in obtaining correct information about the current node position, speed, and direction [62].

- *Network administration:* VANET functions in a dispersed form because there is no centralized administrative entity. When there is no central administrator, nodes are given additional duties.

5. Scenarios of Heterogeneous Vehicular Communication

Many wireless communication methods have been considered to support ITS services. It is difficult to provide good ITS services just through a single wireless network due to the constant topology changes of VANETs and significant mobility. Furthermore, the authors [63] demonstrated that DSRC performs poorly with a large number of cars. Similarly, as the number of vehicles on the road grows, LTE networks become readily overburdened. As a result, integrating several wireless access networks such as DSRC and LTE as a heterogeneous vehicular network seems promising to meet several criteria of ITS services. Various wireless access technologies can be used to facilitate V2I and V2V communications. As a result, selecting the most appropriate and efficient technology for a Vehicular User (VU) that matches the QoS metrics is difficult. Zheng et al. [44]. proposed a new layer called the Heterogeneous Link Layer (HLL). The HLL runs on top of the MAC layer in each radio access network, providing a consistent interface to the higher layers. This new layer may be able to meet the QoS requirements by facilitating cooperation between multiple radio networks.

5.1. V2V Communication

As discussed in Section 2, V2V communication provides direct vehicular communication without relying on permanent infrastructure assistance. In this part, we look at two potential V2V communication mechanisms.

5.1.1. DSRC

The DSRC technology is appropriate for both safety and non-safety services in V2V communications. V2V communications based on DSRC do not conflict with cellular networks because they use distinct frequency bands. Using DSRC in V2V communications, however, poses significant difficulties [26], [64]. Because of the CSMA mechanism's limitations, collisions occur often in densely crowded traffic situations.

5.1.2. LTE D2D

Device-to-Device (D2D) communication is the method by which User Equipment (UE) can communicate directly with each other [65]. As a prospective solution for V2V, D2D communications in LTE confront some obstacles [66], [67]. To begin with, interference is a big worry when using D2D in a heterogeneous vehicle context. In addition, unlike medium or high-speed vehicles, most D2D devices in LTE networks are usually immobile or have low-speed mobility. As a result, D2D communication performance may suffer. Furthermore, due to the existing peer and service discovery of D2D communications, it is not well suited for vehicular.

Contexts. Finally, requesting D2D discovery is a time-consuming task. As a result, the D2D discovery time may be longer than the message transmission time in some circumstances. Due to the tight latency requirements of safety applications, this is not appropriate for transmitting safety notifications.

5.2. Communication of V2I

V2I communication allows a vehicle to communicate with roadside infrastructure to obtain information and data. V2I communication is commonly proposed to be supported by cellular networks. However, another option is to use DSRC in V2I.

5.2.1. DSRC

The IEEE 1609 working group for DSRC networks has created a set of standards to fulfil the needs of vehicular communications. In addition, the IEEE 802.11e Enhanced Distributed Channel Access (EDCA) method has been modified to meet the MAC layer's QoS criteria [68]. Many broadcast protocols for DSRC safety broadcast services have been proposed in the literature [69, 70, 71, 72, 73, 74]. As a result, when using DSRC networks for V2I communications, various issues must be solved.

5.2.2. Cellular networks

In cellular networks, two transmission modes can be used for V2I communications: unicast and multicast/broadcast. Unicast is a point-to-point communication protocol between a vehicle and a base station that can be used for both uplink and downlink message distribution.
Multicast/broadcast, on the other hand, is a point-to-multipoint transmission that is used to disseminate downlink messages. On the one hand, V2I communication can be accomplished using the Wideband Code Division Multiple Access (WCDMA) system. However, because the delivery latency is greater than the demand, this system cannot adequately offer safety services in vehicular communications. LTE, on the other hand, provides a fantastic platform for V2I communication. The LTE system's flat architecture is optimized for reduced transmission delay. Furthermore, the evolved Multimedia Broadcast and Multicast Service (eMBMS) is a cost-effective method of supporting multicast or broadcast services in high-density vehicle situations. LTE networks can provide high capacity and wide coverage. However, there are a few issues to address. Table 1 [7] summarizes the benefits and drawbacks of using DSRC and LTE for V2V and V2I communications. The study in [44] proposed a new layer of HLL because partnerships between heterogeneous networks are critical.

Table 1: Advantages and challenges of key candidates in heterogeneous vehicle communications based on [44].

Mode of Communication	**DSRC**		**LTE/LTE D2D**	
	Advantages	Challenges	Advantages	Challenges
Communication of V2V	-Ad-hoc mode - Small cost and easy installation - Wave Short Message (WSM) overhead is small	-Hidden mode and broadcast storm issues -Channel congestion by numerous vehicles -Sparse pilot development -Adjacent band leaks in multi-channel operation	- Spectral efficiency is High - D2D resource scheduling is Effective - Energy Efficiency in High	- High-speed vehicles degrade in performance - Between D2D pair and other users there is Interference -There is a consumption of time on Peer and service discovery
Communication of V2I	- Small cost and easy installation - local message dissemination is Suitable for i.e. parking information, traffic signals, etc.	- Hidden mode and broadcast storm issues -Channel congestion by numerous vehicles -Sparse pilot development -Unstable link -Prioritization and service selection	-Huge coverage -The capacity for both uplink and downlink is high -The operation of mobility management is tough -efficiency on eMBMS is High -The architecture is Centralized and flat	-High delays in disseminating messages caused by users in the idle state -Prone to overloaded in high-density environments -Lack of efficient scheduling schemes for ITS services

Under this new framework, several candidate technologies can collaborate. Finally, Table 1 shows that DSRC is better for V2V communications than LTE D2D. On the contrary, the LTE cellular network is the best choice for V2I communications.

6. VANET Integration with Various Heterogeneous Wireless Networks

Different radio access technologies (RATs) such as Wi-Fi, WiMAX, 3G, and 4G networks, and diverse cell formats are used in heterogeneous networks. Many researchers have investigated the vehicular networks domain in the literature [28]. However, a few recent articles [44, 75, 22, 23, 24, 25, 26] have focused on the diverse environment of vehicle communications.

The adoption of LTE in automotive networks across heterogeneous wireless networks was the focus of studies in [13] and [23]. In [23]], Vinel et al. examined 3GPP LTE and IEEE 802.11p/WAVE technologies to see whether one might provide cooperative vehicular safety applications. LTE has superior network capacity, better mobility, and greater coverage, but it suffers from higher latency and increased network stress when compared to 802.11p [76].

However, [40] presented hybrid techniques for heterogeneous vehicular communication that combine both LTE and 802.11p. In [77, 78]], various LTE-VANET cooperation were proposed. Zheng et al. found that heterogeneous vehicular networking with LTE for V2I communications and DSRC for V2V communications is one of the best methods for supporting vehicular services in their study [44]. Viriyasitavat et al. examined the optimal channel and propagation models for this heterogeneous network because the vehicular network environment is highly dynamic [31].

Several studies looked at various automobile uses [32], [33]. Similarly, [34] divides existing VANET context-aware programs into three categories: environment, system-and-application, and context-awareness. VANET makes use of a variety of wireless technologies to provide an effective, reliable, and adaptable internet access solution. In [36]], Mane and Junnarkar examined internet access methodologies and foundations in VANET-Internet integration scenarios. This project aims to improve the performance of mobile gateways and data collecting to prioritize the distribution of emergency notifications. However, Gerla et al. [79] identified the urban internet infrastructure's role in clarifying the significance of urban internet infrastructure in supporting growing vehicular applications and highlighted the mobile internet's future in vehicular networks. Furthermore, a recent study in [24] looked at V2I communication in heterogeneous multi-tier networks with a variety of radio access technology (RAT) environments. In [80] Shahid et al. published a survey of several VANET technologies, whereas in [81], a comparison of UMTS and LTE for vehicular safety communication at junctions was reported. The primary wireless technologies for heterogeneous vehicular communications are summarized in Table 3.

Mir et al. [39] also presented a hybrid communication system combining LTE and the WAVE protocol. Furthermore, some research [82], [83] has shown that satellite communication could be used in vehicle network communications. In [84], Li et al. advocated using satellite communication just in the downlink and cellular systems in the uplink. Many studies are now being conducted on seamless connectivity in heterogeneous multi-RAT environments. The majority of this research focused on achieving smooth vertical handover, data distribution, and mobility, while others concentrated on security concerns.

6.1. Vertical Handover

Service continuity, network discovery, network selection, security, device power management, and QoS issues should all be considered and addressed in an accurate VHO process [85, 86, 87], with the latter being the most important. Several approaches [88, 89, 90] divide the VHO process into three stages: (i) obtaining information, (ii) making a decision, and (iii) carrying out the choice. The relationships between the three phases necessary to achieve handover in heterogeneous networks are depicted in Fig. 6.

6.1.1 Information gathering for the handover

Not only network information is collected during the handover information collection phase, but also information about the rest of the system's components, such as network attributes, mobile devices, access points, and user preferences. As a result, this phase is referred to as handover data collection [91], system discovery [92], system detection [93], handover initiation [94, 95] or simply network discovery [96, 97, 98]. The information is collected and processed in this phase to make decisions in the handover decision phase. The following is a typical list of data collected:

- Availability of nearby network links by providing data such as speed, cost, packet loss ratio, handoff rate, Received Signal Strength (RSS), Noise Signal Ratio (NSR), Carrier Interference Ratio (CIR), Signal

Table 2: Input Parameters and Evaluation Metrics Used for Vertical Handover

	Area	Metric	Narrative	Utilized as: Input parameter	Utilized as: Evaluation Metrics
Network	Latency	Latency e2e, Average delay	latency for End-to-end, from sending the packet to receiving a packet	[99, 100, 101, 90]	[100, 97, 101, 102, 103, 104, 105]
		Delay in Network	Amount of time to deliver a packet	[91, 101, 103, 88, 106, 107, 96, 108, 109, 110]	[87, 86, 111]
	Coverage	Network availability, coverage	the network area coverage	[97, 91, 112, 113, 114, 108, 115, 116]	
	Performance	RSS	Received signal strength	[117, 118, 90, 119, 91, 120, 121, 101, 122, 123] [124, 104, 125, 98, 126, 112, 127, 128, 129] [105, 95, 130, 131, 92, 132, 133, 134, 135, 136]	
		CIR	Carrier interference ratio	[119, 101]	
		RTT	Round trip time	[119, 90, 101, 122, 137, 106, 108, 115]	
		Retransmissions	Packets retransmitted	[101, 137]	
		BER	Bit error rate	[100, 91, 119, 101, 87, 127, 88, 107]	
		SIR	Signal-to-interference and noise ratio	[138, 87, 95, 115]	
		Security	The security of the network	[100, 101, 139]	
		Packet loss	Unsuccessful delivery of Packets	[91, 101, 103, 106, 96, 115]	[140, 106, 86, 141, 109, 111]
		Throughput, data rate	Network Throughput	[99, 142, 131, 107, 143]	[1, 138, 122, 124, 87, 104, 144, 126, 127, 137] [106, 86, 95, 145, 115]
		Bandwidth available	Available bandwidth instantaneous in the network	[90, 100, 99, 124, 146, 103, 104, 88, 119, 131] [96, 115, 109, 147]	[148, 116]
		The bandwidth offered, link capacity	The candidate network offered bandwidth	[91, 85, 103, 98, 130]	
		Network Jitter	Jitter induce by the network	[91, 101, 139, 103, 88, 106, 131, 107, 115]	[86, 111]
		Network overhead	Additional management packets in the network		[149]
	Billing	Cost/money	Network price utilization	[100, 91, 101, 139, 124, 87, 150, 103, 98, 88] [92, 143, 96]	[100, 103, 151]
	Miscellaneous	Number of users	Available users in the network	[99, 151]	
User preferences		Budget	Budget user utilization of the networks	[91, 88, 96]	
		Preferred network	User choice	[91, 97, 99, 88, 114, 96, 115]	
Mobile terminal	Location	Mobility, location	Geolocation or AP-based location	[91, 120, 122, 123, 125, 95, 114, 96, 132, 135]	
		Movement	The change in movement direction	[125, 120, 96, 132]	
		Speed, velocity	The speed while moving the mobile terminal	[91, 125, 99, 139, 104, 98, 96, 115, 147]	
		Network interfaces	Technologies available in the device	All proposals are referred	
		Battery consumption	Power consumption	[91, 99, 101, 139, 150, 98, 88, 148, 114, 96] [147]	[148]
VHO	Occurrence	Number of VHO	Events performed by VHO		[90, 125, 87, 122, 142, 123, 124, 150, 98, 112] [152, 133, 95]
		VHO success rate	The success performed ratio of VHO events	[4]	[147]
	Latency	VHO Latency	Time is taken for the VHO process		[1, 4, 126, 153, 113, 154, 132, 136, 109, 155] [156]
		Gathering latency	Time is taken for the VHO Gathering phase alone		[4, 154, 157]
		Decision latency	Time is taken for the VHO Decision phase alone		[4, 154, 157]
		Execution latency	Time is taken for the VHO execution phase alone		[4, 154, 157]
		Dwell time	Length of time the VHO process remains suspended to allow another process to run.	[119, 126, 105, 90]	
	Network	VHO packet loss	Packet delivery failure in the VHO process		[121, 97, 136]

The VHO process requires accurate data collection because the decision-making procedure is based on it. The efficiency of the VHO in terms of optimization in decision-making to connect to the optimal network can also be determined by evaluating its performance. Table 2 shows the many parameters that various authors employed in their proposals and publications. Since vehicles are continually on the move, V2I communication requires a Vertical Handover (VHO) between the vehicle and the infrastructure. However, when the frequency of handovers grows, ping-pong effects emerge. The VHO in VANET heterogeneous wireless networks has been studied in certain articles [158], [159]. In addition, the VANET multi-hop communication model presented in [160] is used in a new handover mechanism. Layer-3 latency is reduced using this approach. Chen et al. proposed a method in which a vehicle leaving the network sends its IP address information to the automobiles behind it as they enter cell coverage. A quick handover can also be done by anticipating the vehicle's movement [161]. Further enhancements to interference management have been presented in [84]. Li et al. studied uplink interference using a Coordinated Multi-Point (CoMP) method, in which user equipment in a multi-coverage area selects a cell with superior connection quality.
A moving vehicle must prioritize selecting the proper target roadside in multi-tier RAT diverse environments.

Table 3: Main wireless technologies for heterogeneous vehicular communications as adapted from [8] and [40].

Feature	**Wi-Fi**	**802.1p**	**UMTS**	**LTE**	**LTE-A**
Frequency band(s)	2.4 GHz, 5.2 GHz	5.86-5.92 GHz	700-2600 MHz	700-2690 MHz	450 MHz-4.99 GHz
Width of Channel	20 MHz	10 MHz	5 MHz	1.4, 3, 5, 10, 15, 20 MHz	Up to 100 MHz
Distance	Up to 100 m	Up to 1 Km	Up to 10 Km	Up to 30 Km	Up to 30 Km
Bit rate	6-54 Mb/s	3-27 Mb/s	2 Mb/s	Up to 300 Mb/s	Up to 1 Gb/s
Coverage	Intermittent	Intermittent	Ubiquitous	Ubiquitous	Ubiquitous
Mobility support	Low	Medium	High	Very high (up to 350 Km/h)	Very high (up to 350 Km/h
V2I support	Yes	Yes	Yes	Yes	Yes
V2V support	Ad-hoc	Ad-hoc	No	No	D2D

And not the incorrect one. Packet losses, ping-pong, and even call drops can occur in these contexts, necessitating a seamless and dependable handover [162]. However, because the performance of 802.11p may be hampered by non-line-of-sight settings, WiMAX technology was developed to allow high-speed V2I communication. With an expected handover delay of less than 30 ms, the IEEE 802.16 m WiMAX version can handle mobility up to 350 km/h [163]. In [164]], the essential phases of a VANET handoff procedure were investigated, as well as several similar research in the literature that reduces VANET handoff time. This study also looked at the rapid handoff systems provided in prior studies to improve the various phases of the handoff. However, [165] discusses the numerous handover needs as well as the essential aspects that influence the handover procedure. Several parameters related to the VHO process were also discussed. Advanced VHO decision-making approaches were investigated. RSS measurements, QoS parameters, and mobile terminal position information are all examples of metrics that might be used to trigger handover decisions. The majority of the research relies on a single-criteria decision-making system. Similarly, in [166], Midya et al. compared various VHO techniques based on criteria such as handoff latency, addressing, technology, and handoff choice.

6.1.1. Vertical handover algorithms

[148]created a VHO decision method that maximizes the aggregate battery lifespan of Mobile Nodes (MNs). This technique allows the proxy nodes, which connect the Adhoc-mode MNs to the nearest AP or BS, to share transit loads to balance their battery power consumption. The suggested algorithms outperform traditional optimization based on the SSF approach, which is solely based on RSS. [25] proposes deploying a System Selection and Mobility Management Agent (SSMMA) on both cars and networks to address handover concerns. Kang et al. [167] provided an optimized vertical handoff solution for the switching problem in a vehicle heterogeneous network interface.
-The strategy incorporates several metrics, including monetary cost, available bandwidth, and data transfer

Delay. Furthermore, it can accurately anticipate RSU distribution. The results show that the optimal stopping-based policy significantly outperforms several existing systems. Considering vehicle speed and network traffic factors, the number of handovers and latency can be reduced, while throughput can be increased [168]. To overcome the ubiquitous handover problem in heterogeneous networks, Bi et al.[169] proposed a performance-guaranteed optimized handover choice method. Vehicles can hand over a diverse environment using this technique, not only to achieve overall load balance among all access points but also to maximize data rate and vehicle fairness. Additionally, the data rates of handover vehicles are assessed during the decision-making process.

6.2. Approaches to vertical handover

Chiu et al. proposed a cross-layer quick handover technique dubbed the Vehicular Fast Handover Scheme (VFHS). To reduce the handover delay, the physical layer information is communicated with the MAC layer in this system. This system results in a speedy handover as well as a significant reduction in handover delay and packet loss. In [171]Ahmed et al. suggested an effective network-aided handover strategy that reduces vehicle scanning time during the handover procedure. The vehicle's RSU is determined by its velocity during the handover. However, the existing system requires a vehicle to scan until all of the nearby RSUs are found, which adds to the scanning time. The results show that the proposed technique effectively reduces the overall scanning delay and iterations that cars often endure. Proposed a new architecture that facilitates seamless mobile network mobility across heterogeneous networks. The overlapped reception of packets from several Access Routers (ARs) utilizing this technology greatly minimizes packet losses during handover while also lowering handover delay. Meneguette et al. [173] designed a Seamless Flow Mobility Management Architecture (SFMMA) to improve vehicular application quality of service. This design is built on vehicular network application classes and mobility management via the network.

The proposed SFMMA works with many network interfaces at once, aiming to reduce handover time, increase network throughput, and meet minimal latency and packet loss requirements for each type of vehicular network application. As a result of this work, the new architecture had a faster handover time, less packet loss, and less delay. Chung et al. [174] have suggested the WAVE Point Coordination Function (WPCF) protocol, a time-coordinated Medium Access Control (MAC) protocol for better V2I communications and handover. When compared to Point Coordination Function (PCF), Enhanced Distributed Channel Access (EDCA), or Hybrid Coordination Function (HCF) controlled channel access (HCCA) for V2I communications, the WPCF protocol can greatly improve utilization efficiency and accommodate more users. As a result, when compared to the performance of existing protocols, the suggested approach can drastically reduce handover delay. A contention-free WPCF changeover channel access method has also been presented to allow high-priority real-time data access.

A Time-Division Multiplexed (TDM) transmission system would waste time slots, whereas the WPCF technique does not. Overall, with the proposed WPCF scheme's preregistration process and efficient, reliable scheduling when opposed to employing EDCA for handover, the service disruption period is substantially less.

Table 4: Vertical handover works‘ comparison (NA: Not Available).

Author Name	**Handover Latency**	**Packet loss**	**Bandwidth**	**Delay**	**Throughput**	**Data rate**
Chiu et al. [170] (VFHS)	Decrease latency	Decreases packet loss	NA	Reduce delay	NA	NA
Gramaglia et Al. [175] (SILVIO)	NA	NA	A higher bandwidth	NA	NA	NA
Chung et al. [174] (WPCF)	NA	NA	NA	High priority real-time data	NA	NA
Dias et al. [176]	NA	No packet loss	NA	Very low delay	NA	NA

Shukla et al. [172]	Without reducing handover latency	Minimizes packet losses	NA	NA	NA	NA
Kumaran et Al. [168]	Minimize latency	NA	NA	NA	Maximize throughput	NA
Bi et al. [169]	NA	NA	NA	NA	NA	Maximize data rate
Dahiya et al. [177]	Reduce latency	Reduce packet loss	NA	NA	NA	NA
Ahmed et al. [171]	NA	NA	NA	Reduce delay	NA	NA
Meneguette et al. [173] (SFMMA)	Minimum latency	Low packet loss	NA	Low delay	Maximize throughput	NA
Joseph & Rajagopal [178]	NA	NA	NA	NA	NA	High data security

Dias et al. [176] suggested a mobility solution that combines MIPv6 and PMIPv6-based extended mobility protocols with a mobility manager that ensures seamless communication between vehicles and infrastructure. This technique can choose the most appropriate technology to keep the vehicle linked without interrupting any ongoing sessions. The suggested approach addresses both Layer 2 and Layer 3 handovers. For Layer 2 changeover, a mobility manager was created that scans available networks and initiates the turnover, while Layer 3 handover control mobility protocols were enhanced and tailored to work with the mobility manager. Experiments in real-world automobiles were carried out utilizing three different technologies: IEEE 802.11p, IEEE 802.11g, and 3G. Because traditional Wi-Fi standards introduce high handover latency and packet loss, it is vital to deploy IEEE 802.11-enabled RSUs in high-demand scenarios, the results indicate the benefits of a simpler communication standard for VANETs. The findings further show that if IEEE 802.11p is employed in both vehicles and RSUs, the suggested method can execute a smooth handover with very little delay and no packet loss.

Furthermore, [79] discussed FMIPv6 enhancement. This enhancement is based on a handover management strategy in a VANET scenario that employs the concept of tunnelling. Several criteria were considered, including handover latency, signalling overhead, performance comparison using tunnelling, packet loss, service disruption duration, and network longevity. Handover delay, packet loss, signalling overhead, the number of packets required for handover, and service disruption time are all reduced. As a result, these strategies must be evaluated in a more realistic setting and applied to a real-world wireless environment.

Gramaglia et al. [175] have suggested Seamless Internet 3G and Opportunistic WLAN Vehicular Internet Connectivity (SILVIO). It's an internet connectivity solution for multi-hop automobile ad-hoc networks. Users can benefit from increased bandwidth while operators can relieve their overburdened cellular networks by adopting SILVIO. SILVIO delivers seamless communication without the need for signalling. Furthermore, the findings of real traffic traces from Madrid City reveal that by employing SILVIO, the cellular network can be offloaded by up to 80%.

In addition, [179] presented a novel hybrid interworking method that allows access to mobile internet and standard IP services via a mobility management mechanism. Furthermore, the system focuses on urban vehicle scenarios and allows for seamless communications regardless of network operator roaming agreements. Despite varied mobility patterns and the heterogeneity of the supporting radio access technologies, this new hybrid method provides for flawless IP session transfer. The provided approach outperforms competing protocols such as the optimized version of MIPv6, NEMO BS, conventional HIP, and Novaczki's micro-mobility scheme for HIP, according to the performance analysis. In contrast, in

[180] an extendable simulation environment was created by merging the simulation tool NS2 with the VANET-Mobisim user mobility model. In NS2, a VHO mechanism based on Media Independent Handover (MIH) and a multi-mode node model are established. Element. The communication capabilities of multi-mode VUs in a heterogeneously integrated UMTS and WLAN network are assessed. The throughput of VUs is only a little affected by their velocity. However, frequent handoffs caused by users' high speeds may compromise user QoS in terms of packet loss and handoff latency.

Furthermore, while other users' modest traffic load may not have a significant impact on user performance, excessive traffic load will reduce user performance, particularly in WLAN. As a result, the upward handoff delay is significantly higher than the downward handoff latency. Ghosh et al. [181] on the other hand, introduced a new VANET testbed that is now being deployed at Middlesex University in London. This research presents a new proactive handover performance model, which is then compared to previous methodologies. A probabilistic approach based on accurate propagation models from a genuine testbed is necessary to reliably derive relevant values of TBVH and NDT. Furthermore, this work demonstrates how accurate TBVH and NDT values may be employed for proactive channel allocation. Furthering handover research, Joseph & Rajagopal introduced a new system [178] that allows effective handoff between WLAN and WiMAX while also providing a big coverage and multimedia application to the vehicle. Location preservation and vehicle security are achieved using Elliptic Curve Diffie-Hellman (ECDH) cryptography with a public key.

Conclusion

The integration of VANET heterogeneous wireless networks in the literature was reviewed and compared in this paper. The success of vehicle communication relies heavily on the integration of VANET heterogeneous wireless networks. On the other hand, this work will aid future researchers in gaining insight into the collaboration of vehicle heterogeneous networks in constructing VANETs and improving driver safety. As a result, it is recommended that researchers test their findings not just in small-scale homogeneous networks but also in large-scale heterogeneous networks.

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