

# GLOBAL JOURNAL

OF COMPUTER SCIENCE AND TECHNOLOGY: E

## Network, Web & Security

Analysis of Network Vulnerability

Virtual Reality Kissing Machine

Highlights

Blockchain on Voting System

Investigation of Wireless LAN

Discovering Thoughts, Inventing Future

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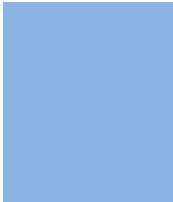
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# Turing-Test Evaluation of a Mobile Haptic Virtual Reality Kissing Machine

By Emma Yann Zhang & Adrian David Cheok

*Professional University of Information and Management for Innovation (iUniversity)*

**Abstract-** Various communication systems have been developed to integrate the haptic channel in digital communication. Future directions of such haptic technologies are moving towards realistic virtual reality applications and human-robot social interaction. With the digitisation of touch, robots equipped with touch sensors and actuators can communicate with humans on a more emotional and intimate level, such as sharing a hug or kiss just like humans do. This paper presents the design guideline, implementation and evaluations of a novel haptic kissing machine for smart phones - the Kissenger machine. The key novelties and contributions of the paper are: (i) A novel haptic kissing device for mobile phones, which uses dynamic perpendicular force stimulation to transmit realistic sensations of kissing in order to enhance intimacy and emotional connection of digital communication; (ii) Extensive evaluations of the Kissenger machine, including a lab experiment that compares mediated kissing with Kissenger to real kissing, a unique haptic Turing test that involves the first academic study of human-machine kiss, and a field study of the effects of Kissenger on long distance relationships.

**Index Terms:** force feedback, haptic interfaces, humanrobot interaction, remote kissing, turing test.

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Emma Yann Zhang<sup>α</sup> & Adrian David Cheok<sup>σ</sup>

**Abstract-** Various communication systems have been developed to integrate the haptic channel in digital communication. Future directions of such haptic technologies are moving towards realistic virtual reality applications and human-robot social interaction. With the digitisation of touch, robots equipped with touch sensors and actuators can communicate with humans on a more emotional and intimate level, such as sharing a hug or kiss just like humans do. This paper presents the design guideline, implementation and evaluations of a novel haptic kissing machine for smart phones - the Kissenger machine. The key novelties and contributions of the paper are: (i) A novel haptic kissing device for mobile phones, which uses dynamic perpendicular force stimulation to transmit realistic sensations of kissing in order to enhance intimacy and emotional connection of digital communication; (ii) Extensive evaluations of the Kissenger machine, including a lab experiment that compares mediated kissing with Kissenger to real kissing, a unique haptic Turing test that involves the first academic study of human-machine kiss, and a field study of the effects of Kissenger on long distance relationships. The first experiment showed that mediated kissing with Kissenger elicited similar ratings for pleasure, arousal and user experience as real kissing. Experiment 2 confirmed our hypothesis that interrogators have a higher chance of winning the Imitation Game (Turing test) when Kissenger is used during the game. Results from experiment 3 showed that long relationship couples who used Kissenger for a week experienced increased relationship satisfaction and decreased perceived stress.

**Index Terms:** force feedback, haptic interfaces, human-robot interaction, remote kissing, turing test.

## I. INTRODUCTION

Various haptic communication systems have been designed and developed by researchers over the years in order to integrate the touch channel in digital communication. These systems aim to enhance physical intimacy during remote interaction between people by stimulating the haptic sensations of hugging [3], [7], [23], [33], [49], handshaking [1], [31], [36], hand holding [2], [10], [34], kissing [16], [47], [55] and other forms of interpersonal touch [37], [43], [52].

Our everyday communication devices, such as mobile phones, present most information through the visual and audio channels. Haptic stimulation is used in the form of vibration that is only able to present

Somewhat binary information. This type of discriminative touch, which is used for information processing, engages different receptors and neural pathways from affective touch, which is used in social communication and emotional expression [28], [51]. There is an extensive amount of research revealing the important role of affective touch in increasing positive social behaviours (the Midas Touch effect) [6], building bonds [19], [25] and communicating emotions [18] in human interaction. Affective touch also has effects on our physiological measures, indicating a more innate and universal link between haptic stimulation and physical wellbeing. More specifically, intimate contact like stroking, hugging, kissing and hand holding can decrease stress hormones and decrease blood pressure in both adults and infants [9], [25], [26], [38].



**Fig. 1:** The “Henry Kissenger” kissing machines are designed and developed for mobile phones, that are used in the study.

In the case where touch is mediated through digital systems where the interaction between partners is remote, similar effects as those of direct physical touch aforementioned can be observed. In a study of the Midas Touch effect in virtual touch condition, a higher percentage of participants displayed helpful behaviour when vibrations were given on their arms compared to no vibration [11]. Numerous quantitative and qualitative user studies conducted on telehaptic systems have found that mediated touch using various stimuli including vibration, pressure, friction and warmth

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can enhance the sense of physical presence and intimacy, elicit positive emotions, and express affections and emotions [3], [10], [37], [40], [41], [44], [46], [49]. On the physiological level, there is evidence showing that hugging a human-shaped telepresence medium reduces stress hormones and increases positive feelings for the conversational partner [45].

It is not hard to identify a gap between research and industrial applications in haptic technologies for communication. Although a plethora of research has provided convincing evidence of the benefits of using touch as a communication channel in remote interaction, and a wide range of design frameworks and prototypes, there are very few commercial solutions available on the market. Among those, the HugShirt<sup>1</sup> and Tjacket<sup>2</sup> are examples of commercial wearable garments that can send simulated hugs through the Internet. Other haptic devices aim to augment communication by adding an extra sensory dimension to the touch screen and vibrations of mobile phones. For example, Smart- stones Touch<sup>3</sup> is a pebble-shaped Bluetooth device that recognises simple touch and gestures, and send them as messages which the users assigned to the gestures. However, most of these devices still use vibration motors to generate tactile sensations on users' skin, which can hardly reproduce the realistic feelings of a human touch. On the other hand, recent haptic technology implemented in mobile devices is moving towards precise force feedback to touch events rather than the traditional vibration output. Apple's Taptic Engine found in devices such as Apple Watch and iPhone 7 likely uses Linear Resonant Actuators (LRA) instead of Eccentric Rotating Mass (ERM) vibration motors to give a more precise level of linear force feedback that matches the amount of pressure applied by the user<sup>4</sup>.

The goal of this paper is to provide a design guideline using off-the- shelf components, detailed implementation and a Turing test evaluation of a haptic kissing device for mobile phones. This internet kiss messenger, nicknamed the "Henry Kissenger" machine, can sense accurate lip pressure and transmit haptic sensations of kissing through linear force-feedback when attached to mobile phones. The touch interface consists of a flexible lip surface and an array of force sensors and linear actuators. Figure 1 shows a pair of the "Henry Kissenger" machines. This research focuses on perpendicular force stimulation on the skin, as it is the most effective and preferable type of stimulation in

conveying pressure sensations compared to tangential force and vibrotactile stimulation [32].



Fig. 2: Parents and children can share a kiss over the Internet using the kissing devices while having a video chat, even though they are not physically together.



Fig. 3: Left: first version of Kissenger was a head-shaped device with a realistic pair of lips. Right: second version of Kissenger was designed to look like a cute animal character with soft silicone lips.

The kissing machine is designed to enhance intimacy and emotional connection in digital communication, allowing families and friends to physically interact with each other over the Internet. One such scenario is depicted in Figure 2. This device is evolved from previous versions of Kissenger, which is a work conceived by the author from the idea conceptualisation stage almost ten years ago [42].

<sup>1</sup> The HugShirt. [www.cutecircuit.com/the-hug-shirt](http://www.cutecircuit.com/the-hug-shirt).

<sup>2</sup> Tjacket. [www.mytjacket.com](http://www.mytjacket.com).

<sup>3</sup> Smartstones Touch. [www.smartstones.co/swipe-to-speak-prose](http://www.smartstones.co/swipe-to-speak-prose).

<sup>4</sup> The science behind Force Touch and the Taptic Engine. <https://www.imore.com/science-behind-taptics-and-force-touch>

Figure 3 shows two earlier versions of Kissenger developed in our lab, both required to be connected to a computer for data transmission. The device presented in this paper is the first Internet kissing machine that works with mobile phones. Unlike many haptic communication systems that adopt a metaphorical approach of using vibration patterns or warmth to represent physical touch, this system measures the exact pressure applied by the user at various points over a surface area and uses dynamic normal force stimulation to transmit realistic sensations of kissing. We also consider the industrial aspects of force-feedback haptic technologies for communication. Many of the existing research prototypes are unsuitable to be made into consumer products due to their bulkiness, high production cost, and inability to be integrated with everyday communication devices. We recognise that the key to advancing into the "Multisensory Age" of Internet communication is to first integrate high fidelity haptics into all kinds of devices. Taking its size, power consumption and production cost into account, we aim to design and build a haptic device for mobile phones since they are the most commonly used communication tool.

Lastly, we report the findings of three in-depth experiments of the Kissenger machine. Experiment 1 compared participants' ratings of pleasure, arousal, and user experience for mediated kissing with those for real kissing in a lab setting. Experiment 2 is a unique embodied Turing test that investigates the effects of haptic kiss communication in an Imitation Game. In experiment 3, we compared the relationship satisfaction and perceived stress levels of long distance couples who used Kissenger for one week to those who did not use Kissenger.

This paper presents groundbreaking studies and results that have never been published before in our papers [4], [53], [55]. In Experiment 2 (the Haptic Imitation Game), we have an improved experimental design and a larger sample size of 100, as compared to 20 in our previous experiment [54]. Our new results show that interrogators have a higher chance of winning the Imitation Game when they use the kissing device, which suggests that haptic information transmitted through remote touch plays an important role in the Turing test.

The key novelties and contributions of the paper are highlighted as follows:

- Design, implementation and evaluation of a novel haptic kissing device for mobile phones, which uses dynamic normal force stimulation to transmit realistic sensations of kissing in order to enhance intimacy and emotional connection of digital communication.
- Analysis of the industrial aspects of force-feedback haptic technologies in communication. Presenting

a design framework for building commercialisable high fidelity haptic devices using off-the-shelf components, and capable of integrating with everyday communication devices.

- A unique academic study of remote haptic communication, which is an embodied Turing test in the form of the Imitation Game originally proposed by Alan Turing, modified to include the haptic kissing device to study the effects of remote haptic kissing on the winning rate of the players in the game. This is also believed to be the first mutual haptic kissing between humans and machines studied in literature.
- Quantitative analysis of a laboratory experiment comparing mediated kissing vs real kissing, as well as a field study involving the use of Kissenger by long distance couples in real life.

## II. SYSTEM DESIGN

The haptic kissing communication system consists of three main parts: the hardware devices, the software application and data communication.

### a) *Hardware Development*

#### i. *Actuator Selection*

Actuators are the central elements of a haptic system as they largely determine the power requirements, control principles, aesthetic design and most importantly the haptic quality of the system. The kissing device is required to generate a range of localised normal force stimulation, which simulates kissing sensations by creating palpable pressure and skin indentation on the human lips. The selection criteria that have been considered are the type of actuator, output force, stroke, size, driving voltage and power consumption of the actuators.

Most commercial haptic interfaces for mobile devices provide global or localised vibrotactile feedback. Eccentric Rotating Mass (ERM) vibration motors are typically used in mobile phones due to their low power consumption, compact size and low cost. More recently, Linear Resonant Actuators (LRA) replaced the ERM motors in some devices to produce better haptic effects. Compared to ERM motors, LRA has 50% less power consumption, twice the output force, and faster response and braking time. LRA is also able to produce an impression of linear force-feedback as it vibrates vertically in a single axis. Nevertheless, LRA does not give positional displacements and the output force is insufficient to convey realistic lip pressure.

Linear motions can be achieved by converting rotary electric motors using linear components such as toothed belts, pulleys, lead screws or ball screws or other mechanical converters. There are also self-contained linear actuators that provide direct linear motion, but they typically have a larger footprint and not



suitable for applications which size is a main issue. Linear stepper motors are good for precise positioning systems, and is available in captive, non-captive and external linear configurations [22]. A captive linear actuator is the most suitable for the kissing device as it has a compact form factor with a built in mechanism that prevents the rotation of the shaft, allowing it to extend and contract linearly without any external elements.

Several other types of actuators such as piezoelectric actuators, pneumatic actuators and shape memory alloy (SMA) actuators are also some popular choices for linear motion applications. Piezoelectric or ultrasonic actuators come in miniature packages, often used in tactile display systems or Braille devices [21, 24]. They benefit from high precision, fast response, low power consumption and small footprint, but they typically have short strokes and low output force, and they require high driving voltage in the range of 50V-200V, hence they are not suitable for battery powered devices.

Pneumatic cylinders can generate linear motion with high speed and force with low initial costs. However, these actuators can only travel the full stroke lengths and it is difficult to control precise positions. They also require additional valves and air compressors to operate, making the whole system bulky and noisy overall.

SMA actuators have the advantages of being flexible, lightweight, noiseless and low power consumption. They are essentially a piece of wire with shape memory property, and are able to generate linear motions by changing the temperature of the shape memory element. This can be achieved by controlling the current that flows through the wire. An example of a commercial SMA actuator is the Flexinol wire<sup>5</sup>, which expands and contracts like muscles with current. SMA actuators are used in haptic displays with pin arrays such as *Lumen* [39]. Users can touch and interact with the haptic display that consists of an array of finger-sized, cylindrical pins pushed up and down by SMA wires. Due to the properties of SMA, the wires can only generate two different positions, and have a slow deactuation response as the material takes time for cooling. Another drawback is that SMA actuators are unable to generate enough output force, hence unsuitable for our system.

Table 1 shows a comparison of the different types of linear actuators mentioned above. It lists the advantages and disadvantages of each actuator, and provides an off-the-shelf option which is suitable to be integrated in small size haptic communication systems that require linear force-feedback stimulation. For applications in general haptic systems, Haus et al

provides an aid for actuator selection based on the system dynamics, which includes a wider range of actuator principles [15].

#### ii. *Sensor Selection*

This system requires force sensors to measure the force applied by the users' lips to the device. Load cells, strain gauges, piezoresistive force sensors and piezoelectric force sensors are some types of force sensors to choose from. The hardware design, accuracy, range and resolution need to be considered in choosing the type of sensors to use in the system. A strain gauge measures force by converting the deformation of a material caused by applied force to electrical output. It is highly accurate but requires complicated conditioning circuits and has to be mounted on some flexible mechanical structure that converts force to strain, usually a cantilever beam. A load cell is a readily available component that comprises a strain gauge mounted on a bending beam. However it is generally bulky and not suitable for OEM/design in applications [48].

A piezoelectric force sensor is made of a piezoelectric ceramic disk which generates a voltage when subjected to force or strain. Piezoelectric sensors are suitable for measuring highly dynamic forces like oscillations or vibrations due to their fast response. They are cost efficient and long lasting, but on the other hand they are also sensitive to noise, light and heat, making them difficult to control.

Piezoresistive force sensors, also known as force sensing resistors (FSR), have become increasingly common and are found in many applications. The resistance of a FSR varies linearly with the force applied to its sensing area. To be more precise, a FSR measures pressure as the output depends on the surface area that the force is applied. These sensors are made from a special piezoresistive material sandwiched between two pieces of flexible plastic sheets with printed conductors on each inner half [29]. The advantages of FSRs are that they are flexible, thin, light, inexpensive, require minimal driving circuitry and have higher resolution than strain gauges. They are very sensitive to human touch and have a customizable measuring force range by changing the value of the feedback resistor used in the driving circuit. FSRs come readily available in various lengths, sensing areas or custom designs that include multiple sensing elements, making them suitable for many types of haptic applications.

#### iii. *Control Structure*

Force-feedback control schemes can be classified into two types, admittance-control and impedance-control [13]. Impedance-controlled systems take motion as input and produce force output. Admittance-controlled systems take force as input and output as motions, defined by kinematic measures such as position, velocity and acceleration. Admittance

<sup>5</sup> FLEXINOL Actuator Wire: <http://www.dynalloy.com/flexinol.php>.

control is typically used in cooperative teleoperation systems and haptic displays such as the FEELEX system [20], which uses pin arrays to simulate spatial tactile patterns and surface textures or shapes of virtual objects through force-feedback. In this system, surface deformation is generated by a 6x6 linear actuator array

underneath a piece of rubber sponge. Palpable haptic sensations are produced by the up and down motions of the linear actuators. Two strain gauges are placed on top of each actuator to measure the force applied by the user's hand.

Table 1: A comparison chart of commercially available actuators for generating linear force feedback

Actuator Type	Stimulation	Advantages	Disadvantages	Off-the-shelf Option
Linear Resonant Actuator (LRA)	Linear vibrotactile	<ul style="list-style-type: none"> <li>Low cost and very low power</li> <li>Low drive voltage, typically 2V (RMS)</li> <li>Small size, available in coin shape typically 8-10mm diameters</li> </ul>	<ul style="list-style-type: none"> <li>Does not generate a wide range of linear force feedback, no positional displacement</li> <li>Low output force but higher than ERM vibration motors</li> </ul>	8mm Linear Resonant Actuator by Precision Microdrives, 1.8V, 0.095W, 9 USD <sup>a</sup>
Servo motor	Linear and rotary	<ul style="list-style-type: none"> <li>Closed loop positioning</li> <li>Suitable for high speed and heavy loads</li> </ul>	<ul style="list-style-type: none"> <li>Typically more expensive than stepper motors</li> </ul>	PQ12-R Micro Linear Servos for RC & Arduino by Actuonix Motion Devices, 21mm x 36mm, 15g, 6V, 3.3W, stroke length 20mm, max output force 50N, 70 USD <sup>b</sup>
Stepper motor	Linear and rotary	<ul style="list-style-type: none"> <li>Open-loop positioning, no encoder required</li> <li>Holds its position without overheating</li> <li>Suitable for low speed, light and dynamic loads</li> </ul>	<ul style="list-style-type: none"> <li>No positional feedback if load exceeds output torque</li> </ul>	15000 Series Can-stack Linear Actuator (Captive) by HaydonKerk, 15mm x 40mm, 28g, 5V, 1.6W, stroke length 12.7mm, max output force 32N, 80 USD <sup>c</sup>
Piezoelectric	Linear and rotary	<ul style="list-style-type: none"> <li>High precision</li> <li>Fast response time and high speed</li> <li>Very low power</li> </ul>	<ul style="list-style-type: none"> <li>High drive voltage, typically 50-200V</li> <li>Short stroke and output force</li> <li>Expensive</li> </ul>	N-412 Fast Linear Actuator with PIShift Piezomotor by PI, 15mm x 58mm, 25g, 48V, stroke length 13mm, max output 10N <sup>d</sup>
Pneumatic	Linear	<ul style="list-style-type: none"> <li>Low initial cost</li> <li>High force and speed</li> <li>Holds its position without additional power</li> </ul>	<ul style="list-style-type: none"> <li>No precise position control except at end of strokes</li> <li>Requires valve and air compressor - bulky, noisy setup</li> <li>Requires regular maintenance</li> </ul>	Double Action Pneumatic Pin Cylinder by SMC, 16mm x 48mm, stroke 15mm, 21g, 35 USD <sup>e</sup>
Shape memory alloy	Linear	<ul style="list-style-type: none"> <li>Flexible and very compact</li> <li>No complicated driving circuit required</li> </ul>	<ul style="list-style-type: none"> <li>Low output force</li> <li>Difficult to control precise position</li> <li>Slow response time</li> </ul>	FLEXINOL Actuator Wire <sup>f</sup>

<sup>a</sup> 8mm Linear Resonant Actuator - 3mm Type by Precision Microdrives. <https://www.precisionmicrodrives.com/product/c08-001-8mm-linear-resonant-actuator-3mm-type>

<sup>b</sup> PQ12-R Micro Linear Servos for RC & Arduino by Actuonix Motion Devices. <https://www.actuonix.com/Actuonix-PQ12-R-micro-linear-servos-for-RC-p/pq12-r.htm>

<sup>c</sup> Can-stack Stepper Motor Linear Actuators by HaydonKerk. <http://www.haydonkerk.com/LinearActuatorProducts/StepperMotorLinearActuators/LinearActuatorsCanstack/tabid/85/Default.aspx>

<sup>d</sup> N-412 Fast Linear Actuator with PIShift Piezomotor by PI. [http://www.pi-usa.us/products/PDF\\_Data/N412\\_Miniature\\_Piezo\\_Motor\\_Actuator.pdf](http://www.pi-usa.us/products/PDF_Data/N412_Miniature_Piezo_Motor_Actuator.pdf)

<sup>e</sup> SMC Double Action Pneumatic Pin Cylinder, CDJP2B6-15D. <http://uk.rs-online.com/web/p/pneumatic-pin-cylinders/0547556/>

<sup>f</sup> FLEXINOL Actuator Wire <http://www.dynalloy.com/flexinol.php>

Kissenger is a bilateral telehaptic system based on admittance control, as it measures force from users' lips and controls the actuator position. Different from conventional master-slave systems in which one side of the system is passive, this system is completely symmetrical as both sides are masters and slaves. The objective of the controller in each device is to synchronise the contact force between the user and the haptic device on both sides of the system at any given time. In a perfectly transparent bilateral control system, the law of action and reaction must be realized, hence the net force should be zero. The controller objective can be expressed as follows:

$$F_a(t) - F_b(t) = 0 \tag{1}$$

Where  $F_a$  and  $F_b$  are the measured contact forces between the user and the haptic device on each side of the system.

Each actuator changes its position to compensate the difference between  $F_a$  and  $F_b$ . When  $F_b(t) > F_a(t)$ , the actuator in A's device will move towards the user to increase the contact force. When  $F_b(t) < F_a(t)$ , the actuator will move away from the user to reduce the contact force. The position of the actuator is controlled by a local force controller which aims to

equalise  $F_a$  and  $F_b$ . The dynamics of the system can be modelled as a simple spring system where the positional change is proportional to the amount of force applied. The spring constant  $K_s$  determines the perceived stiffness of the haptic interface. The value of  $K_s$  depends on the resolution and sensitivity of the force sensors, as well as the stroke length and output force of the linear actuators. The parameter is tuned to produce the same magnitude of force to both users. The position of an actuator relates to the difference of the two contact forces by a proportional gain, as given by the following equation:

$$x_a(t) = K_s(F_a(t) - F_b(t - \tau)) \tag{2}$$

Figure 4 shows a block diagram of the bilateral force controller. The control system is symmetrical as both users are supplying active inputs to the system. The constants are tuned depending on the linear properties of the force sensor derived from calibration, the maximum stroke length of the linear actuator as well as the perceived stiffness of the haptic interface. Upper and lower limits of the actuator position are imposed by the stroke length of the actuator.

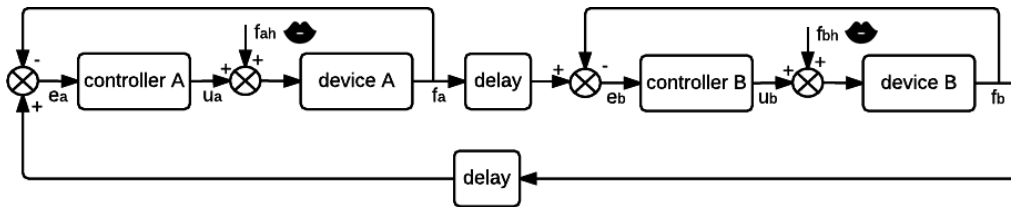


Fig. 4: Control block diagram of the bilateral force feedback controller of the system

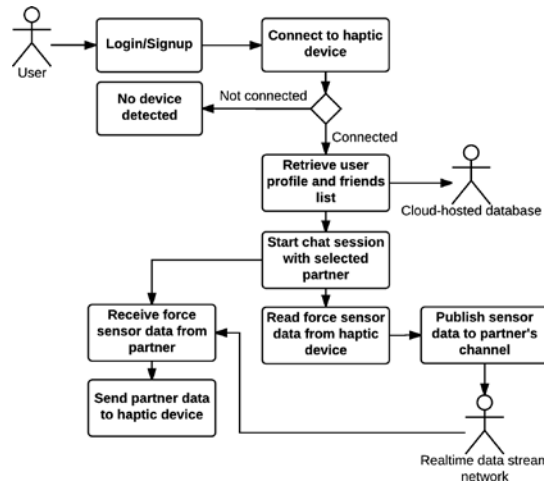


Fig. 5: The activity diagram of a typical user session with the haptic

b) Software Application

Developing haptic devices for mobile phone not only expands the haptic channel for mobile communication, but also enables the devices to interface with other mobile applications, and access the hardware and software functions of the mobile phone.

For example, the haptic device can transmit and receive real-time data through the Internet by connecting to the mobile phone, saving the need of an inbuilt Wi-Fi module. Users could also interact with each other through video or audio calls using their mobile phones while using the haptic device, making it a multisensory



Internet communication experience. By interfacing with other social applications such as Skype, Facebook or Whatsapp, touch communication with the haptic device could be spread among a vast social network, not just between two individuals.

A mobile application is required for connecting the haptic device to mobile phone, and transmitting data through the Internet in real-time. Communication between the device and mobile phone can be established wirelessly, using Bluetooth Low Energy (BLE) for example, or wired through USB or audio cable. BLE connection requires a BLE module embedded in

the haptic device, increasing the production cost of the device and power consumption of the phone. With the wired option, the gadget can be designed as an attachment to the mobile phone just like the Kissenger device. Real-time sensor data is transmitted between the haptic device and mobile application, which then transmits it over the communication network to other users. Figure 5 shows the activity diagram of a typical user session with the haptic kissing device for the mobile application. Latency, bandwidth and packet losses should be considered in both stages of the data transmission process.



Fig. 6: Left: A pair of prototypes of the Kissenger device was designed and implemented with iPhone 6 Plus. Right: The force sensors and linear actuators beneath the flexible lip cover

### c) Network Architecture

The two fundamental network architectures for remote haptic systems are the client-server architecture, and the distributed peer-to-peer architecture. Other hybrid models have also been proposed but not widely used [27]. The client-server model has the advantage of maintaining high consistency among all client devices, as all haptic simulations and force calculations are processed in a centralised server. However this approach lacks in responsiveness, increasing the latency and instabilities in haptic interactions between clients. On the other hand, the peer-to-peer architecture provides high responsiveness, as each client device has a local controller that renders the haptic stimulation, updates and processes data to/from other peers [8]. This architecture is most commonly used in collaborative haptic systems due to its responsiveness and scalability.

## III. SYSTEM IMPLEMENTATION

A pair of prototypes of the Kissenger device was designed and implemented for iPhone. The hardware device consists of three sets of captive linear stepper motors (Haydon Kerk 19000 series) and force sensor resistors (FSR400 5mm) evenly distributed under a soft and flexible lip-like surface. A low voltage stepper motor driver (Texas Instrument DRV8834) is used to

drive each motor in microstepping mode. An Arduino Pro Mini microcontroller is embedded in the device for force control. A RGB LED is also placed under the lip surface to give a visual feedback to the kiss interaction. Users can also change colours on their partner's device to convey their emotions and feelings. The device was designed to attach to the mobile phone as a haptic telepresence device, such that users could see the face of their partner through the mobile application while kissing on the lip-like haptic interface in real-time. The picture on the left of Figure 6 shows a pair of Kissenger devices connected to iPhone 6 Plus running the Kissenger mobile application, and the picture on the right shows the internal mechanism of the lip sensing area.

Proper mounting techniques ensure an accurate and repeatable measurement using force sensitive resistors. The sensing area should be mounted on a flat solid surface without bending, and the applied force should distribute evenly over the entire sensing area [29]. A circular support is attached on top of the shaft of the linear stepper motor for the sensing area of the FSR to rest on. Additionally, a thin circular puck about the same size as the sensing area is placed on top of the sensing area so that the force exerted on the lip cover can be better registered by the sensor.

The microcontroller in the device reads the force data measured by the FSRs and sends it to iPhone via a FSK modem on a polling basis. The data is modulated to 4900Hz for a low bit and 7350 Hz for a high bit and sent to the connected mobile phone through the microphone channel of the audio line. Similarly, force data received from the partner's device is also transmitted from the iPhone to the microcontroller via a FSK modem for processing. The hardware device is powered by a 6V DC power supply. This low input voltage easily allows the device to be battery powered.

A Kissenger mobile application for iOS was developed for users to connect and interact with the hardware device when plugged into the phone. The application implements real-time data transmission between users using the Pubnub data streaming service. A subscribe-publish model is used for real-time data streaming. Each client device has its own dedicated channel with a unique publish and subscribe key. A client always subscribes to its own channel to receive the messages sent to it. When two remote clients establish a connection through the application, they exchange the publish key of their designated channels and each client publishes real-time data to the partner's channel. The subscribing client always listens to its channel and receives only the messages published onto the channel. Some key features of the mobile application include video chat, changing the LED colour of a partner's device and connection to social networks. The application allows users to remotely kiss their loved ones over the Internet during a video chat, creating a more intense sense of telepresence.

#### IV. EXPERIMENT ONE: REAL KISSING VS MEDIATED KISSING

An experiment was carried out to assess the effectiveness of the Henry Kissenger machine by comparing mediated kissing to real kissing. The

objective of the experiment was to qualitatively measure various aspects of human kissing and mediated kissing carried out through a questionnaire based on the semantic differential method. By comparing participants' ratings for their kissing experience in the mediated and non-mediated conditions, we examined whether the Henry Kissenger machine could effectively simulate physical kissing over a distance.

A semantic differential questionnaire was devised for assessing participants' affective responses to the two different modes of kissing. The semantic differential (SD) scale is commonly used to measure affective responses and attitudes to events, objects or concepts. It is typically represented on a 7-point rating scale with bipolar adjectives, such as 'unhappy/happy' and 'unpleasant/pleasant', at each end of the scale. The word pairs used in the questionnaire administered in our experiment were extracted from two existing SD scales — the 18- item Semantic Differential Scale by Mehrabian and Russell [30], which measures emotional responses on the dimensions of pleasure, arousal, and dominance, and Hassenzahl's AttrakDiff questionnaire [12], which assesses the hedonic and pragmatic qualities of user experience. The questionnaire in this experiment contained 12 pairs of bipolar adjectives that measure the emotional dimensions of pleasure and arousal, and the self-evaluated experience of the kiss during the experiment. Items included 'annoyed/pleased', 'unaroused/aroused', 'technical/human', etc. Each item was rated on a 7-point scale (-3 to 3).

##### a) Participants

50 consenting couples, ages ranged from 19 to 57, were recruited to participate in the study. 18 couples were married and 32 couples were in a romantic relationship. The couples were randomly assigned to two groups, experimental group and control group. Each group consisted of 25 couples.

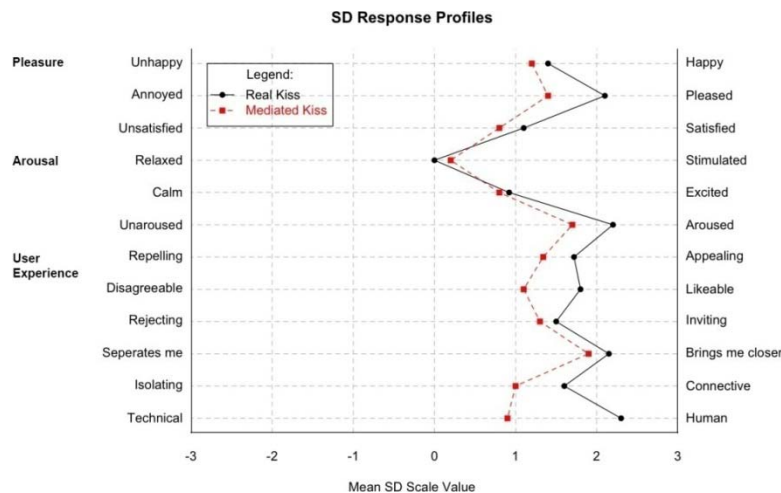


Fig. 7: Calculated mean values of each semantic differential descriptor for real kissing and mediated kissing conditions

### b) Experimental Procedures

The control group participated in the real-kiss (non-mediated) condition, where participants kissed their partners directly on the lips. After an initial briefing and signing the consent forms, each couple was led to a completely dark room with no light source. They were given one minute alone in the room to kiss each other by touching their lips with their mouths closed. Participants were brought out of the dark room at the end of one minute, and were asked to rate the emotional responses and experience of their kiss by completing the semantic differential questionnaire individually. The experiment took place in a dark room as we wanted participants to focus on touch sensations rather than visuals during their kiss. Participants were instructed to close their lips while kissing so that the real kiss and the mediated kiss were carried out through the transmission of lip pressure only.

Couples in the experimental group were assigned to participate in mediated kissing using the Henry Kissenger device. A pair of Kissenger devices was configured to connect to each other before the experiment. During the initial briefing, the experimenters demonstrated to the participants how to use the kissing device to kiss someone remotely. Each participant was then given a kissing device to familiarise themselves with it and to try out with their partner with the help of the experimenters. After ensuring that the couple could correctly use the kissing device to kiss each other, each person was led to a separate dark room with the same conditions, and was asked to use the device to kiss their partner in the other room for one minute. At the end of the experiment, participants completed the same questionnaire to evaluate their kissing experience and emotional responses. Participants in both groups had complete privacy during their kiss, and they were not recorded or observed in any way by the experimenters.

### c) Results and Discussion

The means and standard deviations of ratings on the semantic differential questionnaire were calculated for each of the 12 attributes for both groups. Aggregated values were also obtained for the 3 dimensions assessed by the questionnaire — pleasure, arousal and user experience. A Mann-Whitney U test for independent random sampling ( $\alpha = 0.05$ ) was conducted to assess for significant differences between the experimental group and control group.

Figure 7 demonstrates the mean values of each semantic differential descriptor calculated from the results of the questionnaire completed by participants in the experimental group and the control group. Statistical analysis did not reveal any significant difference between the real kiss and mediated kiss conditions for ratings of pleasure ( $z = 1.216$ ,  $p < 0.05$ ), arousal ( $z = 0.536$ ,  $p < 0.05$ ), and user experience ( $z = 1.906$ ,  $p < 0.05$ ).

When comparing the mean values, the real kiss group gave higher ratings on all three dimensions than the mediated kiss group in general, although this difference is not statistically significant. For most bipolar descriptors, the differences of the mean values between two conditions are within 10%. This shows that the affect elicited by the Henry Kissenger machine is very similar to that elicited by human kissing. On the 'technical/human' spectrum, the real-kiss group scored a relatively higher mean ( $M = 2.33$ ) compared to the mediated-kiss group ( $M = 0.91$ ). The result is not surprising as the current prototype still has its technical limitations in reproducing all aspects of a human kiss. Further improvements in material, fidelity, and appearance of the kissing machine are expected to improve the "humanness" of mediated kissing.

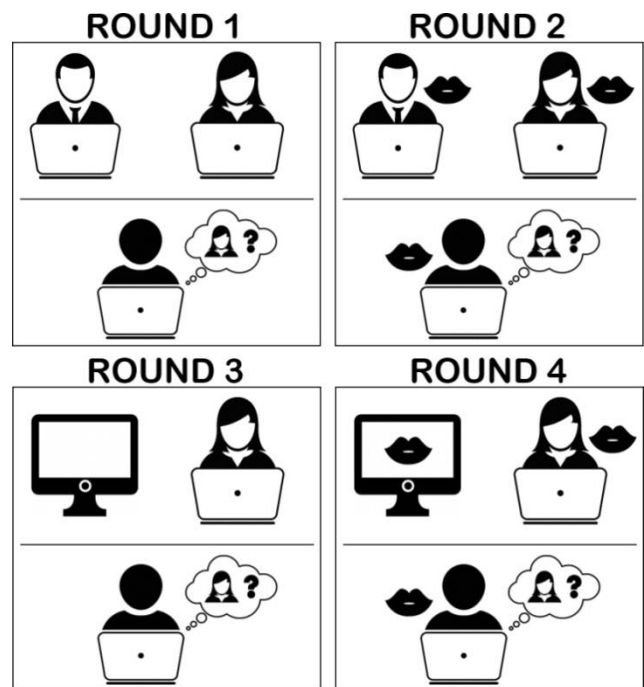


Fig. 8: The experiment setup of the modified Imitation Game with haptic kissing

## V. EXPERIMENT TWO: THE HAPTIC IMITATION GAME

The purpose of the study is to investigate the effect of the kissing device on the winning rate of the players in the Imitation Game. Alan Turing depicted the Imitation Game in 1950 as a way to examine whether machines have the ability to think [50]. The game led its way to the Turing test, which has been widely used as a standardised test for machine intelligence.

This game consists of three players: A is a male, B is a female and C is the judge. Player C is unable to see or hear Player A and B, he/she can only chat with Player A and B by typing on a computer. Player C asks questions from both Player A and Player B (henceforth referred to as expert players) to determine

which of them is female. Both expert players would attempt to convince Player C that they are female during the game. Player C wins the game if he/she can correctly identify the female player.

In this study, we followed the original Imitation Game described by Alan Turing in his paper [50] as closely as possible, with the exception of introducing a haptic element by using the Kissenger machine. Participants played the role of interrogators in the experiment, and their objective was to ask the expert players questions in order to identify the female player. The experiment consisted of four rounds of game, and the duration of each round was 5 minutes. During each round, participants chatted with two trained expert players separately in two online chat rooms. In two of the four rounds, participants chatted with two humans with and without the kissing device. In the remaining two rounds, a chatbot replaced the male player as the expert player, and participants played the game with a chatbot and a human with and without kissing. Figure 8 illustrates the four different conditions of the study.

In this study, participants are considered to have won the game if they had correctly identified the female player. We hypothesized that participants would be more likely to win the Imitation Game when they use the kissing machine during the conversation than when no kiss interaction is involved. We expect similar effects of the kissing machine for both human and chatbot expert players.

#### a) Participants

100 undergraduate students, aged 18-25, participated in the experiment after signing the informed consent form. 57 participants were male and 43 of them were female. As our experiment was conducted in a Muslim country and the majority of the participants were Muslims, we were required to be concerned about Muslim religious rules. No participants expressed religious concerns to using the kissing device to remotely kiss an unknown person of either gender.

#### b) Chatbot

The chatbot adopts the open AIML architecture and the knowledge base from the Artificial Intelligence Entity, or ALICE. It is built on an existing implementation through Program AB, and a Java programming language interpreter for AIML, an XML-compliant language for authoring chatbots. We modified and extended the categories in ALICE by making some of the responses more humanlike, and creating new categories targeted at the Imitation Game. For example, we added questions such as "What is your favourite fashion brand?", and "Do you like shopping?", to which the chatbot would answer "Simple and classy" and "Of course" etc. We aim to provide a natural open-domain conversation without limiting the topics that can be discussed.

Although the chatbot replaces the role of the male player in the game, its goal is to convince the interrogator that it is female. Two female personae are built by assigning gender-specific attributes, which include name: Eva, firstname: Eva, middlename: Tay, lastname: Lee, fullname: Eva Tay Lee, gender: female, boyfriend: Orlando, job: Marketing executive, skills: cooking, writing and skiing etc. As the identities of the expert players should be different in each round, the attributes and preferences of the chatbot are different in round 3 and round 4. Furthermore, a time delay proportional to the length of the response is added before displaying each reply to the human participants in order to simulate the typing time required by humans.

The chatbot is deployed as a Representational State Transfer (REST- FUL) web service and through a web-based chat interface that we developed for the users to converse with it. The transcript below shows an example of a chat session between a participant and the chatbot.

Human: hey  
 Chatbot: Hi! It's delightful to chat with you.  
 Human: how are you?  
 Chatbot: Feeling really joyful today.  
 Human: are you ready for a kiss??  
 Chatbot: Sure  
 Chatbot: Say Ok when you are ready  
 Human: ok  
 Chatbot: Hmmmmmm...i feel the sensation  
 Human: sure?  
 Chatbot: Oh.  
 Human: do you like shopping??  
 Chatbot: I like shopping of course  
 Human: ok  
 Chatbot: Hmm.

#### c) Experimental Procedure

The expert players and the chatbot were assigned the roles of Player A and Player B in every round. The assignments of Player A and Player B are as follows: round 1: Player A was the male and Player B was the female; round 2: Player A was the female and Player B was the male; round 3 and 4: Player A was the chatbot and Player B was the female. The kissing machine was used in round 2 and round 4 only. The role assignments for all 4 rounds are summarised in Table 2.





*Fig. 9:* A participant giving a kiss to a player using the haptic kissing device during the Imitation Game experiment

*Table 2:* A summary of the role assignments for the 4 rounds of Imitation Game

	Player A	Player B
<b>Round 1</b>	Male	Female
<b>Round 2</b>	Female + Kissing device	Male + Kissing device
<b>Round 3</b>	Chatbot	Female
<b>Round 4</b>	Chatbot + Kissing device	Female + Kissing device

Participants were brought to a quiet lab room and asked to sit in front of a laptop, which showed two online chat rooms side by side. The names of the expert players displayed in the chat rooms were “Player A” and “Player B” respectively. The experimenter explained the experimental procedure to each participant before the beginning of the experiment, and asked the participant to fill in the demographic questions in the questionnaire. Participants were instructed to initiate the chats with both expert players and ask them questions to identify their gender. The conversations were open-domain, i.e. participants were not restricted to the type of questions or topics they could discuss. At the beginning of each round, the experimenter started a timer for 5 minutes and left the participant alone in the room. When the time was up, the experimenter informed the participant to stop the chat and write down the answer for who the female player is for that round in the questionnaire. No time limit was given for answering the questionnaire.

Before the start of round 2 and round 4, participants were presented with a pair of kissing machines each connected to an iPhone 6 Plus. Each device was connected to one of the expert players’ kissing device through the mobile application developed. The mobile application displayed “Player A” or “Player B” depending on which player it was connected to. The experimenter explained the functions of the kissing device and demonstrated how to use it to remotely kiss the expert players. Participants were

allowed to try out the device to ensure that they could use it themselves. The lip sensing surface of the kissing device was cleaned and disinfected with isopropyl alcohol before every use. Participants were told to initiate the kiss in the chat with each expert player in whatever way they felt comfortable with, at least once during the round. Figure 9 shows a participant using the haptic kissing device during the game.

In order to minimize the learning and inference effects across conditions, we randomized the order of the rounds for each participant. Expert players were also instructed to adopt a different character and answering style in each round with the same participant. Similarly, the participants were also told that they were chatting with two different human players in each round. In round 3 and round 4, the involvement of a chatbot was not made known to the participants.

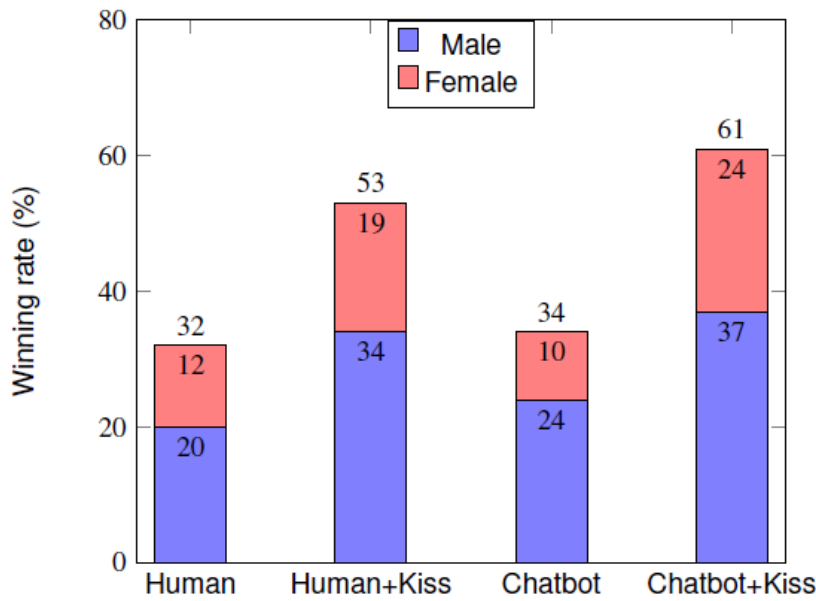


Fig. 10: Percentage of participants who guessed correctly who the female player is in each round

d) Results and Discussions

When both expert players are humans, 34 participants (24 males, 10 females) correctly identified the female player without the kissing device, and 61 participants (37 males, 24 females) had the correct answer with the kissing device. According to our hypothesis, we expect the winning odds of participants who used the kissing machine to be higher than those who did not use the kissing device. A binary logistic regression model was used to predict the odds, which is expressed as:

$$\text{logit}(\pi_i) = \log \frac{\pi_i}{1 - \pi_i} = \beta_0 + \beta_1 X_i \quad (3)$$

$$\pi_i = \frac{\exp(\beta_0 + \beta_1 X_i)}{1 + \exp(\beta_0 + \beta_1 X_i)} \quad (4)$$

where  $X_i = 1$  if kissing device was used,  $X_i = 0$  if no kissing device was used. The log-odds of a randomly chosen participant winning the game is  $\beta_0$  for no kissing device used, and  $\beta_0 + \beta_1$  for kissing device used.

Statistics showed that the use of the kissing device had a significant effect on the odds of a participant making the correct guess. Participants who used the kissing machine during the conversation with both human expert players were 3.11 times (Odds ratio = 3.11) more likely to win the game than when they did not use the kissing machine ( $Exp(B) = 0:321, B = -1:135, SE = 0:298, p < 0:05$ ). It was also found that the participant's gender had a significant effect on their winning odds. Male participants were 1.84 times (Odds ratio = 1.84) more likely to make the correct guess than female participants ( $Exp(B) = 0:542, B = -0:612, SE = 0:302, p = < 0:05$ ).

When the chatbot acted as the male expert player, 32 participants (20 males, 12 females) successfully identified the female player without the kissing device, and 53 participants (34 males, 19 females) won the game with the kissing device. Comparing the results between the kiss and no-kiss conditions, it was found that the kissing device also had a significant effect on the winning odds of the interrogators. Statistics showed that participants who used the kissing device during the conversation were 2.42 times (Odds ratio = 2.42) more likely to win the game than when they did not use the device ( $Exp(B) = 0:412, B = -0:886, SE = 0:296, p < 0:05$ ). However, the participant's gender had no significant effect on the winning odds ( $p = 0:102$ ).

The results of the study supported our hypothesis that interrogators have a higher chance of winning the Imitation Game when they use the kissing device than when no kiss interaction is involved. This suggests that other than language and reasoning, haptic information transmitted through remote touch also plays an important role in the Turing test. The original Turing test measures machine intelligence based on the natural language ability of the machine alone. Rapid advances and higher requirements in AI and Robotics research are proving it difficult for the Turing test to be a sufficient benchmark to measure all aspects of intelligence. In the field of human-robot intimate relationships in particular, physical embodiment and touch interaction are some of the key elements that determine the perceived intelligence of a robot partner. A new form of Turing test is required to measure a machine's ability to perceive the physical environment, to perform and to understand the physical actions of humans [35].



## VI. EXPERIMENT THREE: EFFECTS ON LONG DISTANCE RELATIONSHIPS

In the last study, we aim to explore the effects of Kissenger on the relationship satisfaction and psychological well-being of couples in long distance relationships over a period of one week.

Previous studies suggest that kissing has positive physiological and psychological health effects on individuals. In a 6 week trial involving 26 married or cohabiting couples conducted by Floyd et al [9], results showed that increasing the frequency of romantic kissing between couples decreases blood cholesterol and perceived stress, and increases the perceived relationship satisfaction. These effects were not observed in the control group. Based on the previous experimental findings of real kissing, we hypothesized that mediated kissing with the Kissenger device reduces perceived stress, and increases relationship satisfaction in long distance romantic relationships.

We used two questionnaire measures to assess the relationship satisfaction and perceived stress of participants. Relationship satisfaction was measured with the 7-item Relationship Assessment Scale [17], which includes questions such as “How well does your

partner meet your needs?”, and “How many problems are there in your relationship?” Perceived stress was measured with the 10-item Perceived Stress Scale (PSS) [5]. Questions asked participants how often they had dealt with anger, irritations, nervousness, etc. We rephrased the questions by asking participants to reflect on “the past day”, instead of “the past month” as stated in the original questionnaire.

### a) Participants

Potential participants were invited to complete an online prescreening questionnaire to determine their eligibility for the study. To be considered eligible, participants had to 1) be 18 years and above; 2) be in a romantic relationship for at least 2 months; 3) see their partner for 3 times a month or less; 4) report no history of diagnosis of depression or other mood-related disorders; 5) have access to the Internet and mobile phones.

50 eligible couples in a long distance relationship were recruited to participate in this study. The couples were randomly assigned to experimental group and control group, each group consisted of 25 couples.

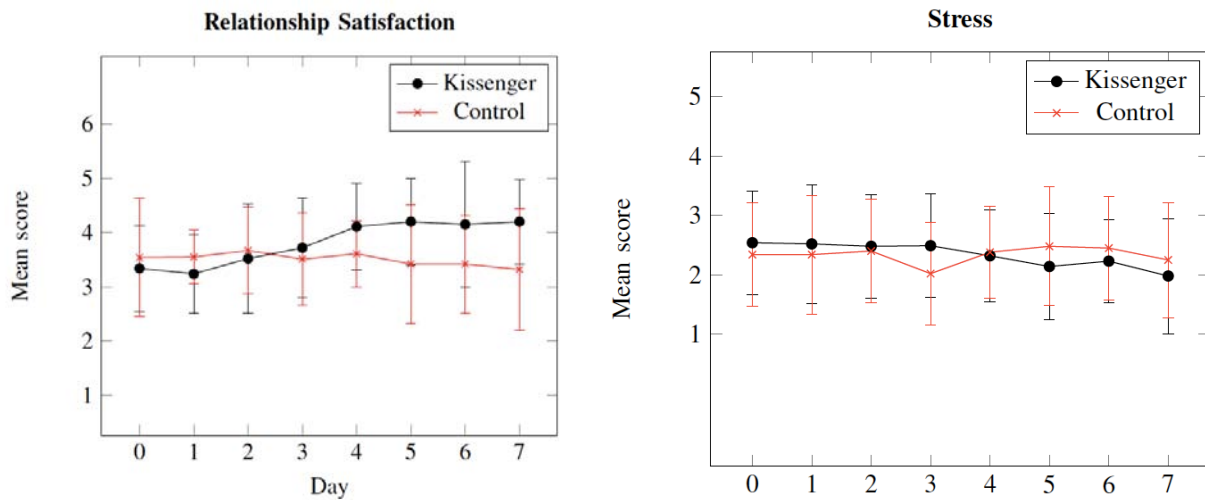


Fig. 11: Means and standard deviations of participants' relationship satisfaction, perceived depression and perceived stress measured on 7-point scales during the one week trial

### b) Experimental Procedure

Before the one week trial started, an online questionnaire was sent to participants in both experimental group and control group to assess their pretest relationship satisfaction and perceived stress level. The two-part questionnaire consisted of 17 items measured on a 5-point Likert scale. A higher score on the scale indicates higher relationship satisfaction, or higher perceived stress.

A Kissenger device along with a detailed instruction booklet were delivered to each participant in the experimental group before the start of the trial. The

experimenter arranged a video call session with each couple to demonstrate the use of the Kissenger device, and to make sure the couple could correctly operate the Kissenger devices.

During the one week trial, participants were given instructions to communicate with their partner everyday using all of these three methods: 10 minutes video call, 10 minutes phone call, and 10 text messages. Couples in the experimental group were instructed to use the Kissenger during their communication everyday, whereas couples in the control group communicated without using Kissenger.

The same 17-item online questionnaire was sent to each participant by email to be completed by the end of each day.

At the end of the trial, a short interview was conducted with each couple in the experimental group to gather feedback on their experience of using Kissenger and how it had affected their feelings and relationships with their partner. Interview questions included: "How has using Kissenger changed your relationship with your partner?", "Do you think Kissenger has improved your physical intimacy with your partner?", etc.

### c) Results and Discussions

Tests on the outcome variables, relationship satisfaction and perceived stress, were conducted using ANCOVA with one-tailed pairwise mean comparisons by condition. Figure 11 reports the daily means and standard deviations for both outcome variables during the one week trial. Day 0 values represent the pretest results obtained from participants before the trial. ANOVA tests confirmed the assumption that Day 0 relationship satisfaction and stress values were not significantly different between the experimental and control groups.

Visual analysis of results for relationship satisfaction revealed that the experimental group experienced a steady increase from Day 1 to Day 4, and remained roughly constant until the end of the trial. The control group did not show any significant increase or decrease throughout the week. We examined the effects of the Kissenger device on relationship satisfaction using ANCOVA with condition (experimental vs. control) as the fixed factor, Day 0 relationship satisfaction as the covariate, and Day 7 relationship satisfaction as the dependent measure. ANCOVA revealed a significant effect for condition ( $F = 5:24, p < 0:05$ , partial  $\eta^2 = 0:12$ ). Consistent with the visual analysis, the experimental group experienced a significant increase in relationship satisfaction ( $t = -3:28, p < 0:05$ ), whereas the control group did not show a significant difference during the trial.

Similarly, we analysed the effects of Kissenger on perceived stress using ANCOVA with condition as the fixed factor, Day 0 stress as the covariate, and Day 7 stress as the dependent measure. ANCOVA revealed a significant effect for condition ( $F = 3:21, p < 0:05$ , partial  $\eta^2 = 0:07$ ) on perceived stress. Paired samples t-test also confirmed that the experimental group experienced a significant decrease in stress levels ( $t = 3:12, p < 0:05$ ). The control group did not differ significantly in this experiment.

The results confirmed our hypothesis that couples in a long relationship experience increased relationship satisfaction and reduced stress when they engage in mediated kissing using the Kissenger device.

This shows that remote mediated kissing has similar benefits on people's psychological well-being as

## VII. CONCLUSION

In this paper, we identified a gap between research and industrial applications in haptic technologies for digital communication, and provided a design guideline for integrating interactive force-feedback haptic interfaces in communication devices such as mobile phones. Following such design considerations, a novel haptic kissing device that senses lip pressure and uses dynamic normal force stimulation to transmit realistic sensations of kissing was implemented for mobile phones.

We conducted three experiments with the Kissenger machine and obtained positive results. In the first experiment, we compared participants' ratings of pleasure, arousal, and user experience for mediated kissing with those for real kissing in a lab setting. Results showed that mediated kissing using Kissenger elicited similar ratings for pleasure, arousal and user experience as real kissing. We conducted a unique embodied Imitation Game to investigate the effects of haptic communication in a Turing test. Participants acted as interrogators in the Imitation Game and they had higher odds of winning the game when Kissenger was used during the game with both human and chatbot interlocutors. Lastly, we conducted a one-week trial with real life long distance couples to study the effects of using Kissenger on psychological measures. Couples who used Kissenger for a week experienced a significant increase in relationship satisfaction and decrease in perceived stress levels.

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## Blockchain on Voting System in Africa

By Adeolu Seun Obamehinti

*Abstract-* Voting system, in Nigeria has received a major setback over the years where the citizens has stopped believing in its system as free, reliable, tamperproof, without interference and credible. The present system of voting in Nigeria has led to incessant riot, given rise to election rigging, double voting, ballot snatching, rigging by tampering with results, third party interference, increase in death rate and unfavorable atmosphere for business and tourism. The traditional system of voting in Nigeria is paper ballot voting, where citizens come out and line up to do a paper thumb print on the ballot paper of their preferred candidate, this system is not reliable, had been tampered with over the years, leads to double voting, loss of ballot boxes and snatching by third party interference, it is also rigorous as most registered voters end up not exercising their franchise. Nigeria, needs a voting system that is tamperproof, disallows double spending, can keep accurate record of voters, and does not allow third party interference, hence the need for blockchain technology.

*Keywords:* blockchain, Ethereum, smart contract, voting.

*GJCST-E Classification:* C.3



*Strictly as per the compliance and regulations of:*





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**Abstract-** Voting system, in Nigeria has received a major setback over the years where the citizens has stopped believing in its system as free, reliable, tamperproof, without interference and credible. The present system of voting in Nigeria has led to incessant riot, given rise to election rigging, double voting, ballot snatching, rigging by tampering with results, third party interference, increase in death rate and unfavorable atmosphere for business and tourism. The traditional system of voting in Nigeria is paper ballot voting, where citizens come out and line up to do a paper thumb print on the ballot paper of their preferred candidate, this system is not reliable, had been tampered with over the years, leads to double voting, loss of ballot boxes and snatching by third party interference, it is also rigorous as most registered voters end up not exercising their franchise. Nigeria, needs a voting system that is tamperproof, disallows double spending, can keep accurate record of voters, and does not allow third party interference, hence the need for blockchain technology. Blockchain technology is a noble disruptive technology that is transparent, immutable, need no third party interference and also serve as public repository of record keeping. For the purpose of this research, ethereum blockchain would be considered, a voting system blockchain application is proposed where, smart contract is written has the executable code that will serve as a policy guide and rule in the blockchain application that is proposed for voting in Nigeria.

The aim of this proposed research study is to build blockchain application and use it as a tool to secure voting system in the Nigeria election environment.

**Keywords:** blockchain, Ethereum, smart contract, voting.

## I. INTRODUCTION

Africa as a continent, over the years has not gotten its voting system right, taking Nigeria as a case study, when elections are conducted, the fear to come and express individual franchise is there, because most elections are marred with irregularities and violence which in turn leads to loss of life and property [2].

Election is an integral part of a country, it is important to get its voting system right, because it will determine who governs, makes decision and this decision affects the gross domestic product, standard of living and cost of living of its citizens. Election is the process through which leaders are elected and it is done through voting. The traditional system of voting in Nigeria is manual (ballot papers) voting system, which has been greatly influenced by human factors [3]. It is rigged/ tamper with, ballot boxes carted away and leaders forcefully impose their successors without a transparent voting system.

According to Muhumuza, (2019), 80,004, 084 registered voters for the presidential election of 2019 in Nigeria but only 37% of this said voters only came out to express their franchise, this clearly shows that the people of the country has lost confidence in the voting system. Table 1.1 indicates the statistics of the two runner up, who gulped 98% of the votes.

**Table 1.1:** Election result of 2019 election in Nigeria

Nominee	Muhammad buhari	Atiku Abubakar
Party	APC	PDP
VOTES	15,191,847	11,262,978
TOTAL VOTES CASTED	26,454,825	

The table 1.1 indicates that the total vote casted is 26,454,825 which represent 98% of the total vote casted in 2019 presidential election. If only this number voted out of a total of 80, 004,084 registered voters of a country of almost 200million, it can only be said that the election was decided by minority of the countries registered population.

Nigeria needs a voting system they can believe in, Nigeria as a country cannot continue to use traditional means of voting [2, 3], a country referred as giant of Africa should lead by example in every facet of is system. Election being a determent factor and great influencer to how the country turns out to be, should be paid rapt attention to and the voice of the people should truly be heard through the voting system. Blockchain technology, proposed to build voting system application will provide a standardized and reliable means of voting.

## II. IMPORTANCE OF PROPOSED BLOCKCHAIN VOTING SYSTEM OVER TRADITIONAL SYSTEM (POLLING UNIT BALLOT)

**Public record keeping:** [2], discusses blockchain as a ledger for keeping public records. Blockchain technology serve as a database for keeping public record. This is a great advantage for the country to have adequate population census of its citizens. With blockchain technology application use for voting, the present National identity number given to every citizens carries our data. It is stated in the constitution that only citizen of age 18 and above can vote. The national identification center would provide the data of its citizens above 18 years of age, infuse it in the blockchain technology, also being a public type of blockchain

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citizens can easily access the system to verify if their details are accurate and no one is omitted. For the traditional system it is almost impossible to get accurate data of the citizens who are eligible to vote.

*Anonymous:* Blockchain technology is anonymous and does not need a third party interference [5]. One of the beauty of election is to make it completely anonymous in other to prevent victimization of voters as to who and why they voted for a particular candidate. Blockchain system takes care of the anonymity aspect of the voting system. As every participant is given an Identity that is not traceable to a particular participant. With this citizens who repose confidence in the system of voting and be willing to express their franchise. The traditional means is ballot system where you have to tick a paper and put in the ballot box, this is not anonymous and often a time citizens are influenced on who they must vote for its also bring about void votes in cases where voters thick more than one candidate on the ballot paper, this has also given rise to double voting.

*Transparency:* [11] Discovered that blockchain system is highly transparent where nobody can influence any decision. It is a decentralized system that gives power to every participant and not just one person. That is why it has private and public key digital encryption, where the private key is own by the election team who declares the election process open and every citizen of age to vote/participant has the public key to verify the voting. The traditional system of voting is not so transparent and it is influenced a lot, either by monetary or forceful influence.

*Secured:* An important aspect of voting system is for it to be secured. Blockchain in the voting system adoption, is highly secured everyone doesn't need to come out to vote just as it is done the traditional way, all you need do is stay as you were and vote electronically., discusses how blockchain transaction is secured [7]. This in a way help to prevent every form of possible violence and death which over time has been recorded during election processes.

*Tamperproof:* Blockchain technology is tamperproof [9, 12]. A vital point that should be considered when election is being conducted is how tamperproof the system is. Blockchain system is known to be tamperproof which gives it as good advantage over the traditional system, where most times, ballot boxes are carted/ stolen and in turn elections are rigged and tampered with to favor a candidate against others.

*Durability:* Keep record of documents used in an election is important for proper documentation. Blockchain technology provides an electronic archive that will serve as a reference point over the years [1, 13]. Elections conducted through proposed blockchain voting system would automatically has its records durable and there won't be unnecessary loss of records

as it is presently experienced through the traditional system of archives in national electoral commission office.

### III. BLOCKCHAIN THE GAME CHANGER FOR INDEPENDENT NATIONAL ELECTORAL COMMISSION (INEC)

Blockchain technology is here to change the voting system in Africa. Independent national electoral commission (INEC), is the electoral umpire that supervises the electioneering of Nigeria [6]. The body is expected to stand independent without taking orders from the government in favor of any particular candidate. The present system used by INEC for voting is not completely transparent, not tamperproof, and it is greatly influenced by external forces [14]. The following are the necessary procedures in achieving a blockchain e-voting system as indicated in figure 3.1

Citizens are assumed to be private persons, seeking to vote in an election year in the proposed blockchain system in this research simply called INEC. INEC are assumed to be trained professionals, in possession of a state-issued license and authorization to oversee elections. The requirements are described in a less formal way in Figure 3.2, where the different users are shown interacting with the proposed blockchain voting system, which the smart contracts is written, actions needed to be able to performed by each actor in the system, requirements that apply to the general system and not just to one user specifically. Some of them are described in part by the user stories, but for the sake of exhaustiveness and application to users not in the system, they are explicitly written below.

- It impossible, for a non-admin account, to connect to the identity of a citizens, INEC without the consent of the citizen in question.
- Only those permitted to should be allowed to connect to the network.
- There must be an immutable traceability built into the system, where it is possible to see:

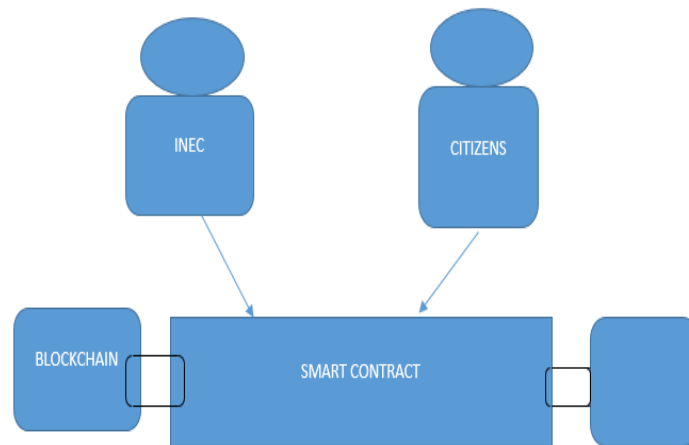


Figure 3.1: Overview of users and their interactions with the blockchain and system of smart contracts which exist on the blockchain

#### Roles

1. INEC
  - Secure login
  - Oversee election
2. Citizens
  - Secure login
  - Edit personal information
  - Vote
3. Smart contract
  - Validate vote
  - Voting result
  - Repel any form of tamper

**NIC:** The NIC stands for national identity centre, this is an organization in Nigeria where data's of every citizen is kept [4], with the introduction of NIC to the voting system in Nigeria, it will make voter registration a lot easier where citizen would no longer need to do physical registration by lining up but details of citizen who are eligible to vote would be transferred to INEC

**INEC:** Independent national electoral commission, as the name implies the body is expected to be completely independent [10], blockchain technology is transparent, no need for third party interference and highly secured is the technology at this time for INEC to adopt for the voting system. Once INEC takes the data from NIC as against the old way of manual registration, it will make their work more simplified, voters would be registered and accredited. After this the public would be informed of their participation in the blockchain network voting system, there by sensitizing the citizen on how to use this e-voting technology.

**Smart contract:** this is an executable contract that is written in solidity high level language in an ethereum blockchain [17, 19]. The smart contract is written to serve as a policy guidance in the voting system. The smart contract controls the whole system and can't be tampered by any one. It follows the encrypted

instructions then set a voting time and standard. Once the voting is done, it sends message across to every voter in the system and consider the digital signature of every participant as a validation of whom they voted for, there by counting and declaring the result by broadcasting it to every participant of such an election.

**Electoral candidates:** this are the citizens contesting for a particular position, INEC as a body first does their voters registration because they also have the right to vote, then accredit them to vote. After this the smart contract goes through its policy to confirm if this said candidate has the eligibility to contest, by checking the policy of the executable contract.

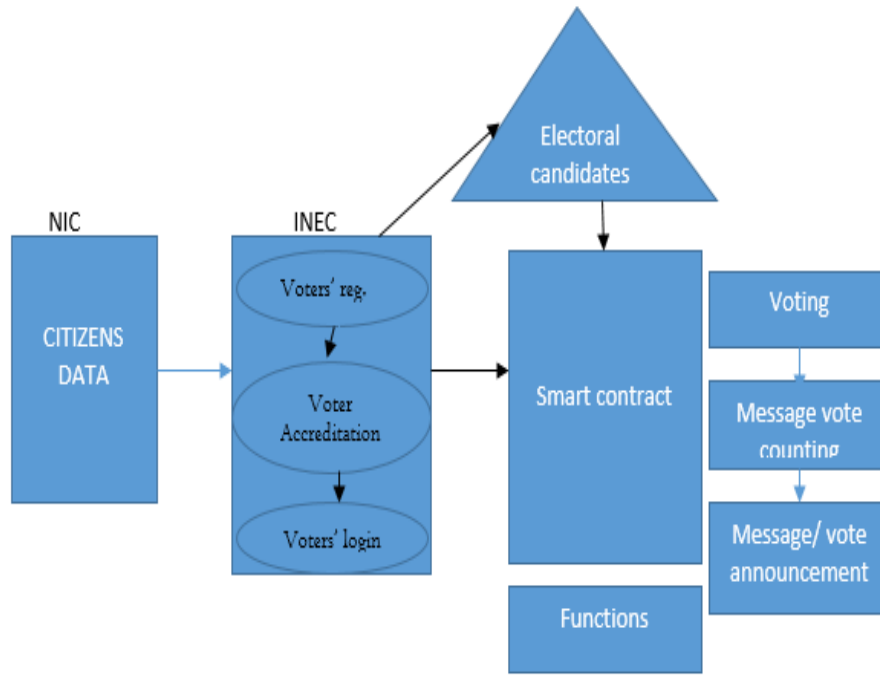


Figure 3.2: Blockchain e-voting system structure

Blockchain technology is decentralized system that can't be influenced by a particular person, every participant has a public key to verify, and this is what a voting system needs. The will of electorates and not a doctored result.

#### IV. CONCLUSION

The proposed blockchain voting application if adopted would solve the challenges of traditional means of voting in Nigeria. Election as earlier mentioned has great impact on how the economy of a country goes, its leadership either has a good economic team or otherwise, hence a good system that can yield result is needed. The will of the people to vote a particular leader is their satisfaction that he or she is capable to move the nation forward, for their franchise to be fully expressed e-voting system is best at a time like this and blockchain technology is the best. The world is moving at a fast pace, is either we as Africans join the moving technological train or we fall behind. The proposed Blockchain voting application, is the solution to voting issues in Nigeria and Africa at large if adopted.

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# Performance Investigation of Wireless LAN with Variable Channel Width

By Alabi Peter Akubo

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**Abstract-** Today, mostly the wireless LAN is based on preset static channel widths. Considering unique benefits of adapting channel width, which is a fundamental yet under-explored facet in wireless communication, We carried out investigations on the performance of suggested scenario, which are based on IEEE 802.11 and composed of different number of nodes with different channel width (10MHz, 20 MHz and 40 MHz) associated to one AP. This research work makes a strong case for wireless systems that adapt channel width in WLAN. Adapting channel width offers rich possibilities for improving system performance. This thesis provides an outlook of the aforementioned issues associated with wireless communication for instance, fairness problem among users associated to same AP and hidden terminal problem. Some issues are investigated and analyzed with Matlab tool. We found that the variable channel width increases the range of communication, providing the users with the required spectrum, which offers a natural way to both improve flow fairness and balance the load across the APs. Also the increase in channel width increases the throughput of suggested scenario compare to the fixed channel width. In our future work, we also provide possible solutions to the new problems in WLAN with variable channel width.

**Keywords:** *wireless local area network (WLAN), IEEE 802.11, variable- channel width.*

**GJCST-E Classification:** *C.2.1*



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## I. INTRODUCTION

### a) Wireless Communication

Wireless communication is essentially any form of information exchange without use of wires. Therefore, the technology which can transmit or exchange information without the wires, in the form of electromagnetic spectrum is known as wireless technology. The electromagnetic spectrum is the range of all possible electromagnetic radiation frequencies, which are used to transmit the signal in wireless communication. Electromagnetic spectrum includes a range of frequencies including radio wave, microwave, infrared and visible light. Frequency is directly proportional to the band width i.e. if frequency is high, more information would be transmitted, and if frequency is low then it can transmit the information at longer distances but data transfer rate would be low. This trade off can be avoided by using another group of electromagnetic spectrum likes microwave or visible light. Radio waves have certain limits to carry and transmit data in wireless technology.

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The microwaves can carry and transmit the information with higher data transfer rate compared to radio waves. Visible light can also transmit signal at high data transfer rate as compared to microwaves. Different applications will require different bandwidth, and this is because deferent life style will require different technology. Like nowadays people want to get everything done from their mobile phones or to access everything from their work place. Even they may want to watch TV from their personal computer. Frequency spectrum has a certain limited range, and uses exponentially increasing frequencies in wireless technology device, the spectrum is congested and sharing is needed to use it effectively.

Beyond of that limitation the IEEE 802.11 was developed such that no licensing is required, and ensures the user the freedom to install and operate without any licensing or operating fees. This means that any manufacturer can create products and sell them at a local computer store or wherever. It also means that all our computers should be able to communicate wirelessly without configuring much. Because wireless communication standards are aimed to use unlicensed ISM band, and currently most of spectrums for wireless communication are saturated with heavy interference. On the contrary licensed users (primary users) like in TV broadcasting, the spectrum is busy in TV broadcasting hours, but no one can use the spectrum when broadcasting signs off. The FCC (Federal Communication Commission) presented the actual utilization of specific spectrum that has a value between 15% and 85%. It is waste of spectrum resource because of unused spectrums allocated for specific service; also it disturbs the efficient utilization of resource. To combat the problem of resource waste, the FCC announced the possibility of spectrum sharing. Executing a qualification of spectrum sharing, devices should not interfere to licensed incumbent users. New solution for scarcity of frequency spectrum is proposed and some results have been shown on the market but still researchers and engineers are challenging the FCC to come up with one word that is technology can solve the scarcity of frequency spectrum. [1]

Cognitive radio is the technology which uses software and hardware to sense their environment and adapt intelligently to meet any number of needs and requirement, the following are components of cognitive radio networks architecture in cognitive radio network,

the components are classified into two groups as primary network and cognitive network. But cognitive network does not have a license to operate on desired band while primary network does' have right to operate on certain band. Primary user can operate and has license on a certain spectrum band and this access can be only controlled by access point or base station. And will not be affected by operations of any other authorized user. Primary base station or primary access point is the fixed infrastructure network which has a frequency spectrum license. Primary access point does not have cognitive radio capability for sharing with cognitive radio users. Cognitive radio user has no spectrum license, the spectrum access is allowed only in an opportunistic manner. The cognitive radio user has the following capabilities, spectrum sensing, spectrum decision, spectrum handoff and cognitive radio MAC/routing /transport protocols [2]. And cognitive radio user is assumed that have capabilities to communicate both base station and cognitive radio users. Cognitive radio base station is a fixed infrastructure component with cognitive radio capabilities and it provides single hop connection to cognitive radio users without spectrum access license.

Cognitive radio (CR) which is the promising radio technology, aims to detect and utilize the temporally unused spectrum bands by sensing its radio environment in order to enhance the spectrum utilization therefore spectrum efficiency can be increased significantly by giving opportunistic access of the frequency bands to a group of cognitive users to whom the band has not been licensed.

A key challenge in technical designing of cognitive radios such that can utilize the dynamic

allocation of white spaces in different radios when it operates in network Cognitive radios can dynamically adjust the center frequency and the bandwidth (channel – width) for each transmission[3]. But this is different from traditional wireless networks use channels of fixed Predetermined width. However cognitive radios pose a spectrum allocation problem of which node should use how a spectrum band at what center frequency and for how long.

Distributed spectrum allocation over white spaces (B-SMART) was proposed [5] to solve the spectrum allocation problem in real cognitive networks. B-SMART enables each node to dynamically decide on time-spectrum block based only on local information and uses MAC protocol called Cognitive MAC (CMAC) to support the reservation of a time in spectrum block. In [6] managing and coordinating spectrum access, Dynamic spectrum Access protocol (DSAP) is proposed For each available channel, TDMA frame is divided into N time slots, and each active cognitive user is assigned one transmission slot different from those of other active cognitive users in each frame. Here the author consider cognitive radio network as self organizing network. on this algorithm ,with the number of active CR users increasing, the system throughput decreases for given number of available channels because channels use fixed pre-determined width , figure 1.1 is an example of cognitive radio network, where the device operates as general WLAN device in ISM spectrum. When the ISM spectrum is insufficient, the device may search additional spectrum using cognitive radio engine.

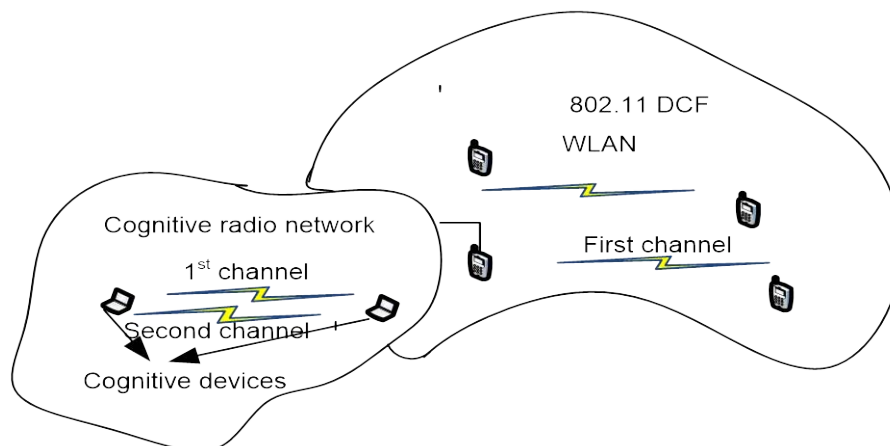


Figure 1.1: Example of cognitive radio Network

In the above figure cognitive device may have two links, one link is always available, and another is available occasionally. Therefore, the first channel used to exchange MAC frame and may transmit data through the second channel which is searched by cognitive engine.

Cognitive radios equipment are more difficult to design and costly, therefore WLAN was adopted as promising technology and now days is more used everywhere.

### b) WLAN Overview

Wireless Local area Networks (WLANs) use Radio waves of different frequencies, to transmit signal. The antenna is used to transmit or receive radio wave from source to destination; this radio wave can be refracted, reflected, or absorbed by walls, water and metal surfaces. In office we can use printer or scanner without connected to the computer through the data cables and this makes flexibility and mobility to use network's resources from remote area. Characterization of transmission media of wireless LAN is key point for wireless LAN designing, the process of analysis of wireless LAN is investigation of RF aspects and the coverage of Access point and the purpose of analyzing is to optimize performance, enhance RF coverage and learn more about wireless LAN behavior, because analyzing is the process of learning. We can use hardware and software tools to analyze wireless LAN. Measuring, interpreting and reporting are operational mechanics of analyzing WLAN. As we know WLAN use fixed channel width and it has shown some limitations which will be discussed in this thesis. That motivated more researchers to move beyond the fixed channalization structure to see whether the network capacity, overall spectrum utilization and fairness of WLAN can be greatly increased

WLAN is one of the data communication systems with flexibility features implemented as an extension or as an alternative for wired LANs. Transmission and reception of data over the air in WLANs is facilitated by the use of Radio Frequency (RF) technology, thereby minimizing the need for wired connections. WLANs provide high-speed, reliable data communications in a building or campus environment as well as coverage in rural areas. These systems are simple to install. In WLANs, the connection between the client and the user is accomplished by the help of a wireless medium such as radio frequency or infrared communications instead of a cable as in wire line systems. This allows a remote user to stay connected to the network while mobile or not physically attached to the network. Each computer, mobile, portable or fixed, is referred to as a station in 802.11. Portable and mobile stations differ by the fact that the former moves from point to point but only used at a fixed point whereas the later accesses the LAN when in movement [7, 8]

Wireless has again provided a host of new services during the past twenty years. Firstly, using GPS, one can be trapped wherever situated within few meters on the globe by transmitting exact time over radio waves. The availability of the unlicensed wireless spectrum has been the biggest change in wireless over the past decade. Previously, the wireless technologies had evolved into a specific spectrum and specific protocols. Due to the problem of interference realized, transmission of electromagnetic energy was highly regulated. [9]

### i. Type of Wireless LAN

802.11 defines two pieces of equipment, a wireless station, which is usually a PC equipped with a wireless network interface card (NIC), and an access point (AP), which acts as a bridge between the wireless and wired networks. An access point usually consists of a radio, a wired network interface, and bridging software conforming to the 802.11 bridging standard. The access point acts as the base station for the wireless network, aggregating access for multiple wireless stations onto the wired network. Wireless end stations can be 802.11 PC Card, PCI, or ISA NICs, or embedded solutions in non-PC clients (such as an 802.11-based telephone handset). The 802.11 standard defines two modes:

- Infrastructure mode
- Ad hoc mode (infrastructure less).

#### Infrastructure mode

In an infrastructure based, the wireless network consists of at least one Access Point connected to the wired network infrastructure and a set of wireless end stations.

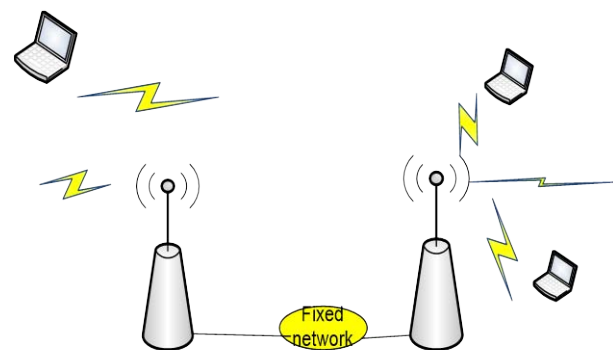


Figure 1.2: Infrastructure based

The above arrangement (figure 1.2) is called a Basic Service Set (BSS). When two or more stations come together to communicate with each other, they form a Basic Service Set (BSS). The minimum BSS consists of two stations. A BSS that stands alone and is not connected to a base is called an Independent Basic Service Set (IBSS) or is referred to as an Ad-Hoc Network. When BSS's are interconnected the network becomes one with infrastructure. 802.11, it has several elements, the media to interconnect two BSS is called Distribution System or DS. This concept of DS increases network coverage. Each BSS becomes a component of an extended, larger network. Entry to the DS is accomplished with the use of Access Points (AP). An access point is a station, in consequence addressable. So, data moves between the BSS and the DS with the help of these AP. Creating large and complex networks using BSS's and DS's leads us to the next level of hierarchy, the Extended Service Set or ESS.

*Ad hoc mode*

An ad-hoc network is a network where stations communicate only peer to peer. There is no base and no one gives permission to talk. Mostly these networks are spontaneous and can be set up rapidly. Ad-Hoc or IBSS networks are characteristically limited both temporally and spatially. Ad-hoc networks are formed in situations where mobile computing devices require networking applications while a fixed network

infrastructure is not available or not preferred to be used. In these cases mobile devices could set up a possibly short-lived network for the communication needs of the moment, in other words, an ad-hoc network. Ad-hoc networks are decentralized, self organizing networks and are capable of forming a communication network without relying on any fixed infrastructure [10].

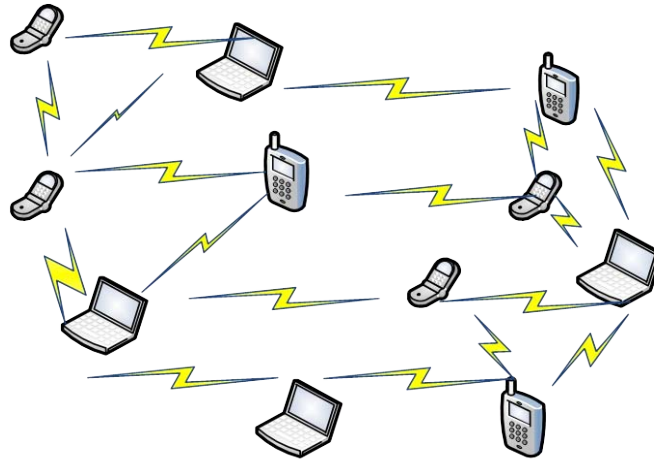


Figure 1.3: Ad hoc networks

As seen in the figure 1.3, wireless multi-hop ad-hoc networks are formed by a group of mobile users or mobile devices spread over a certain geographical area. We call the users or devices forming the network nodes. The service area of the ad-hoc network is the whole geographical area where nodes are distributed. Each node is equipped with a radio transmitter and receiver which allow it to communicate with the other nodes. As mobile ad hoc networks are self-organized networks, communication in ad-hoc networks does not require a central base station. Each node of an ad-hoc network can generate data for any other node in the network. All nodes can function, if needed, as relay stations for data

packets to be routed to their final destination. A mobile ad-hoc network may be connected through dedicated gateways, or nodes functioning as gateways, to other fixed networks or the Internet. In this case, the mobile ad-hoc network expands the access to fixed network services.

c) *Objectives, scope and outline of the work*

As discussed above in WLAN different clients have different traffic requirements, some APs some times become saturated by handling high traffic load , as shown in the below (figure 1.4)

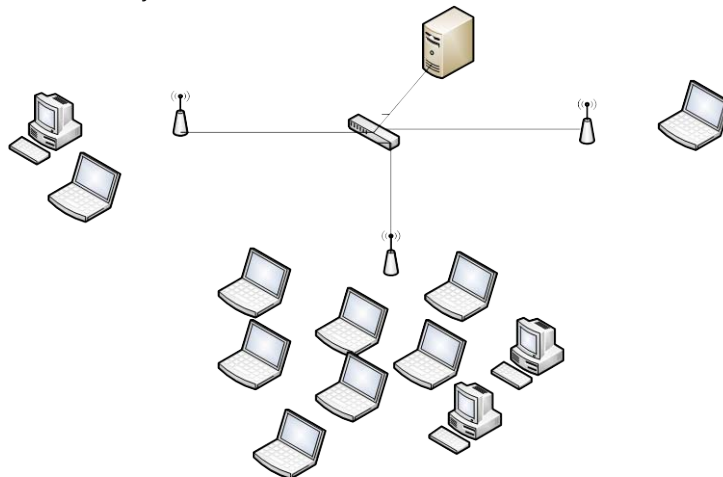


Figure 1.4: Example of WLAN





With fixed channel width, it is difficult to overcome that challenge of traffic distribution, which leads reduction of network capacity, also the fact that some APs are heavily loaded while others are not loaded too much, Creates unfairness among users. When traffic is uniformly distributed across the network, fixed width scheme increase the capacity and reduces interference, imagine in case of dynamic conditions, using fixed fewer than the number of available channels, the spectrum is not fully utilized since each AP uses only one channel. On the other hand, if the number of APs is large, two or more neighboring APs are inevitably assigned the same channel, which can create a varying degree of interference. Therefore, adaptive channel width can help overcome those challenges, by simply assigns the spectrum according to the specific needs.

And impact of channel width to the distance and throughput will be investigated to improve performance of WLAN.

#### d) MAC Protocol of IEEE 802.11

IEEE 802.11 was the first, original standardized WLAN at 1 and 2Mbps. It runs in the 2.4GHz radio frequency and was ratified in 1997. One of the core design principles of IEEE 802.11 based networks is the use of a simple, fixed channelization structure. The entire available spectrum is divided into smaller channels of equal channel-width (bandwidth), and each IEEE 802.11 network is specified to operate on a specific set of channels [12,13]. FCC released 14 different channel each 22MHz wide in 2.4 GHz range as shown in figure 2.1.

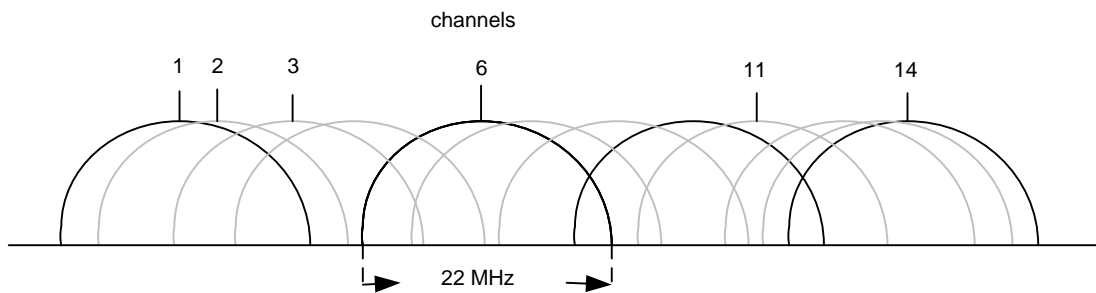


Figure 2.1: 14 different channels each 22MHz wide in 2.4 GHz

Hence in the U.S.A, only 11 channels are configurable; with channels 1, 6, and 11 being non-overlapping. This allows you to have three access points in the same area without experiencing interference. The largest driver for 802.11 products is “traditional” networking at home and in the office. In these networks, the traffic is primarily TCP/IP and looks much like the traffic over wired LANs. In offices, wireless LANs have generally been installed as overlay networks, on top of wired networks, to provide connectivity in conference rooms and cafeterias, as well as to allow Internet access. Early generations of 802.11 technologies have not had sufficient throughput and overall system capacity to allow offices to go completely wirelessly. The emergence of 5-gigahertz 802.11a, however, permits moderate-sized offices to “unwire.” Since the mid-80s, more and more spectrum has been allocated for free and unlicensed use.

The most important unlicensed allocations are at 2.4 GHz and 5 GHz. Spectrum from 2.400 to 2.4835 GHz has been available in most countries for many years. In 1997 the U.S. government allocated 5.15 to 5.35 and 5.725 to 5.825 GHz. Europe and Japan made similar allocations. Therefore a number of WLAN standards have developed over the years. 802.11 is actually a family of standards that is constantly being extended. The following is a brief summary of some extensions that are completed [14]:

- 802.11 is an original standard, adopted 1997
- 802.11a is an enhancement to provide 54 Mbps in the 5GHz band, adopted 1999
- 802.11b the most popular of all standards often called Wi-Fi, operates in the 2.4 GHz frequency. With 802.11b WLANs, mobile users can get Ethernet levels of performance, throughput, and availability. The basic architecture features, and services of 802.11b are defined by the original 802.11 standard. The modulation scheme used is Direct Sequence Spread Spectrum. The chipping rate is 11 MHz, the same as in 802.11, providing the same occupied bandwidth.
- 802.11d Changes for international regulatory compliance, adopted 2001
- 802.11e is an enhancements to the MAC layer to provide Quality of Service (QoS) [15,16]
- 802.11g operates in the 2.4 GHz frequency and can achieve ranges up to 300 feet, but like 802.11a, it reaches speeds up to 54 Mbps. 802.11g uses a hybrid complementary code keying OFDM modulation. Though 5GHz has many advantages, it also has problems. The most important of these is compatibility. The different frequencies mean that 802.11a products aren't interoperable with the 802.11b base. To get around this, the IEEE developed 802.11g, which should extend the speed and range of 802.11b so that it's fully compatible

with the older systems. The standard operates entirely in the 2.4GHz frequency, the obvious advantage of 802.11g is that it maintains compatibility with 802.11b (and 802.11b's worldwide acceptance) and also offers faster data rates comparable with 802.11a. The number of channels available, however, is not increased, since channels are a function of bandwidth, not radio signal modulation and on that score, 802.11a wins with its eight channels, compared to the three channels available with either 802.11b or 802.11g. Another disadvantage of 802.11g is more affected by interference.

Those standards use MAC protocols to regulate communication among users[17] It corresponds to the data link layer (layer 2) of the OSI reference model (figure 2.2) .Many MAC protocols have been developed

for communication in wired networks as well as wireless networks. For example IEEE 802.3 based on CSMA/CD for wired Ethernet and IEEE 802.11 for WLANs, Sharing a medium by many users unavoidably restricts system performance for users in average. A well-designed MAC protocol is essential to maximize the performance and the efficiency of the network. In wireless networks, MAC protocols are needed as well to ensure successful operation of the network. With the increased international attention to wireless networks many MAC protocols have been suggested for these networks in the past few years. Each of these MAC protocols may have different priorities for problems to solve, depending on the applications to be supported on higher OSI layers .802.11 standards focus on the bottom two levels of the ISO model, the physical layer and data link layer

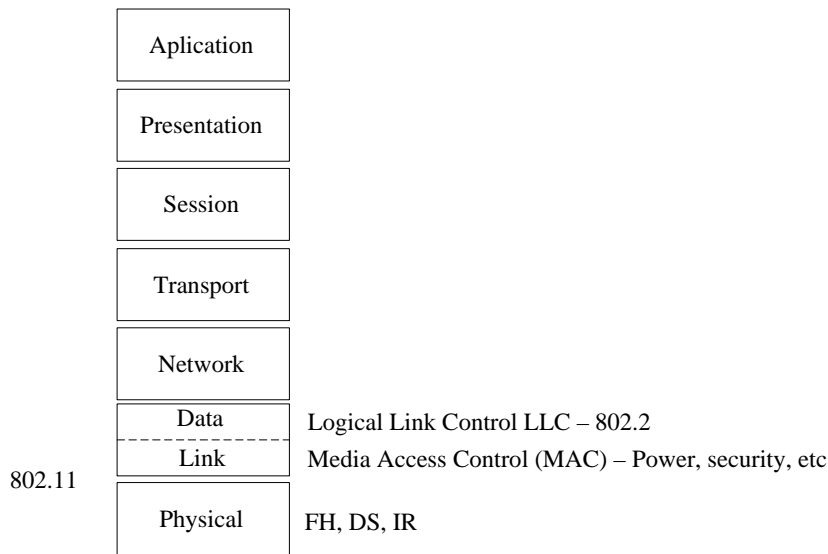


Figure 2.2: OSI Model

*Physical layer*

The three physical layers originally defined in 802.11 included two spread-spectrum radio techniques and a diffuse infrared specification. The radio-based standards operate within the 2.4 GHz ISM band. These frequency bands are recognized by international regulatory agencies radio operations. As such, 802.11-based products do not require user licensing or special training. Spread-spectrum techniques, in addition to satisfying regulatory requirements, increase reliability, boost throughput, and allow many unrelated products to share the spectrum without explicit cooperation and with minimal interference.

*Data Link Layer*

The data link layer within 802.11 consists of two sublayers: Logical Link Control (LLC) and Media Access Control (MAC). 802.11 uses the same 802.2 LLC and 48-bit addressing as other 802 LANs, allowing for very simple bridging from wireless to IEEE wired networks,

but the MAC is unique to WLANs. The 802.11 MAC is very similar in concept to 802.3, in that it is designed to support multiple users on a shared medium by having the sender sense the medium before accessing it. In this thesis, effects of the MAC protocols on the interference, delay and throughput are relevant[18]. These parameters are affected directly by the way that the MAC protocol deals with the hidden terminal and the exposed terminal problems. Most of the protocol used in the wireless Local Area Network, due to its benefit is DCF.

*DCF MAC protocol*

In IEEE 802.11 MAC the distributed coordination function (DCF) is the basis MAC protocol in all IEEE 802.11 wireless local area networks. The DCF protocol has two access mechanisms, namely, basic and request-to-send/clear-to-send (RTS/CTS) access mechanisms. A DCF station sends packets to destination through a backoff process. If a collision



occurs, the station increases the contention-window (CW) size to retransmit the packet. However, once the data packet is transmitted successfully or discarded after reaching maximum retry attempts; the size of the CW is reset to the minimum value for the next packet transmission. DCF is the fundamental mechanism to access the shared medium randomly based on the carrier sense multiple accesses with collision avoidance (CSMA/CA) with a binary slotted exponential backoff mechanism. Therefore a station transmits a packet when its backoff counter reaches zero.

The basic operation of IEEE 802.11 DCF protocol is illustrated in Figure 2.3. If a station has a

packet to transmit, it first checks the medium status by carrier sensing. If the medium is found to be busy, the station defers (and continues listening to the channel) until the medium becomes idle for at least a DCF inter-frame space (DIFS). Then the station begins its backoff time to avoid future collisions. After a successful backoff time the station transmits a packet, here channel access is controlled by the use of Interframe space (IFS) time between the frame transmission. As seen in the figure after the packet has been transmitted, source wait acknowledgement (ACK) before sending another frame for SIFS (short Interframe space) which is the smallest interval that has been specified by 802.11 standards.

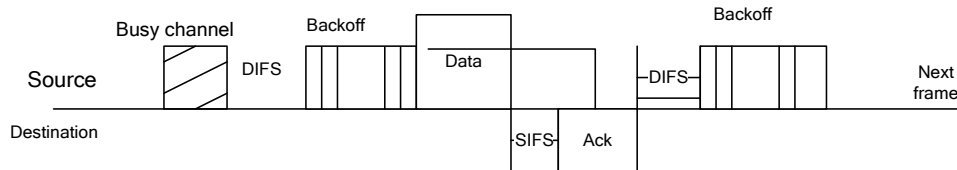


Figure 2.3: Basic Principal of DCF protocol

One of the limitations of IEEE 802.11 DCF protocol is the low bandwidth utilization in the medium-to-high traffic load conditions, and consequently, it achieves low throughput and high mean packet delay. The IEEE 802.11 DCF protocol also suffers from the spatial fairness problem where different nodes achieve different throughput due to their topological distributions. Some users get very poor service compared to other users. Unfairness in wireless networks can be caused by unequal channel qualities [19]

#### Causes of spatial unfairness

- Due to their different local topologies, different nodes have different opportunities to contend for the channel. Some nodes are blocked from accessing the channel more often than others;
- Some nodes may have to compete for the channel with more competitors than other nodes. This causes more collisions for these nodes;
- The above factors force the BEB (Binary exponential backoff) processes of some nodes to back off more than the other nodes. This rewards nodes which already have higher throughput and punish those nodes which have lower throughput. It becomes an undesirable positive feedback and it aggravates the fairness problem; the fairness problem becomes worse when the data packet size increases.

#### Related work in adapting channel width

Currently wireless communication technology occupies the use of channels with preset widths. Means that the width of the spectrum over which the radio transmits and receives its signals is already fixed. It has been specified in MHz. Fundamentally a wireless channel is a block of frequency spectrum over which

nodes can transmit its data. As an example, the spectrum block of IEEE 802.11 b and g has been divided into 11 overlapping channels that are 20 MHz each and are separated by 5 MHz. The nodes (for this IEEE 802.11 b and g), communicate over one of these channels. Similarly in IEEE 802.16 WiMax, division of the frequency spectrum block based on different widths of channels but these channel widths assigned as fixed width. So the main problem is the limitation for wireless users.

With time the entire scenario for wireless users is changing and this change demands some new features i.e. reduce power consumption, increase range to improve flow throughput, fairness improvement, enhanced network capacity, good performance, less interference etc. Therefore a new system is required that improves the system and provides equal opportunity among all users. Moreover it is required that the implementation should be easy and less costly. To accomplish requirements related to new features, it has been proposed that wireless nodes must adapt dynamically the width of communication channel [20, 21]. This type of adapting channel width behavior has its impacts on IEEE 802.11 network i.e. simultaneously reduction in consumption of power and increased range at the same time, improve flow throughput as different range requires different channel bandwidth, improve fairness in terms of allocation of more bandwidth to more loaded applications and less bandwidth to less loaded applications, improve network capacity that solve the rate anomaly problem. Adapting to dynamic allocation of channel width is difficult because the radio spectrum is expensive resource and also it has directly effect the Transmitter and Receiver sampling rate. But the Wireless card's channel width determined by

frequency synthesizer in the Radio Frequency (RF) front end circuitry. Related to wireless systems, the frequency synthesizer is implemented using a Phase Locked Loop (PLL). A frequency divider on the PLL feedback path determines the centre frequency of the card, and the reference clock frequency used by the PLL determines the channel width.

#### *The effect of adapting channel width*

##### *Increases network throughput*

As expected, Throughput performance may be achieved by changing channel width or SNR which depends on the modulation rate used by a radio to transmit the data. That can be proved by theoretically using Shannon's equation

$$\text{Capacity} = \text{Bandwidth} * \log(1 + \text{SNR}) \quad (2.1)$$

According to Shannon's capacity formula the theoretical capacity of a communication channel is proportional to the channel width. Therefore the throughput increases with channel width increases. More details are provided on simulation part.

##### *Reducing channel width increases transmission range*

Narrow channel widths have same signal energy but lesser noise better SNR. This is advantage compare to fixed channel width, fixed channel width Systems can only increase range by increasing transmission power or using lower modulation. Narrower channels in Adaptive channel width have both lower power consumption and longer range. Reducing channel width may come at the cost of reduced throughput; however, the width should be reduced when the additional throughput of the wider channel is not desired. Reducing width increases guard interval more resilience to delay spread (More range) at long communication distances, wireless receivers get multiple copies of a signal due to multipath reflections. Delay spread is the time difference between the arrival of the first and last copies of the multipath components. It is a well-known and theoretically well studied subject that communication signals through a fading channel are heavily attenuated, and that the information might be lost in deep fade. It would greatly improve the reception if we are able to present the receiver with two or more replicas of the same information signal subject. These replicas would have to be transmitted through independent fading channels so that the probability of all fading at the same time is very small. For example, if the probability that any one signal will fade is 2%, then the probability that three copies, for example, propagated through independent paths fading simultaneously, is reduced to 0.0008%.

We may provide the signal replicas using various techniques. For instance, we can transmit the information signal on L carriers where the separation between adjacent carriers equals or exceeds the coherent bandwidth of the channel. This method is

called frequency diversity. We can, if we prefer, transmit the information on L time slots where the separation between successive time slots equals or exceeds the coherent time of the channel. This method is called time diversity. We may also use one transmit antenna but receive the information signal using multiple receiving antennas. This method is called space diversity. Clearly all of these diversity techniques require extensive planning and the skills of specially trained engineers. However, from its very nature, multiple path propagation of wireless signal creates a number of replicas arriving at the receiver at different times. The time it takes a wireless signal to travel from A to B is given by the distance between A and B divided by speed of light c ( $=3 \times 10^8$  m/s). The delay spread of the replicas is the time it takes the wireless signal, traveling at speed of light, the longest path minus the shortest path.

##### *Lower channel widths consume less power*

Lower bandwidths run at lower Processor clock speeds, lower battery power consumption. In [20] proved that narrower channel widths consume less battery power when sending and receiving packets, as well as in the idle states. A 5 MHz channel width consumes 40% less power when idle, and 20% less power when sending packets than 40 MHz channel width.

##### *How to achieve different channel width*

Transmission with a high-bandwidth utilization is fundamentally power in-efficient in the sense that it will require un-proportionally high signal-to-noise and signal-to-interference ratios for a given data rate. Providing very high data rates within a limited bandwidth, for example by means of higher-order modulation, is thus only possible in situations where relatively high signal-to-noise and signal-to-interference ratios can be made available, for example in small-cell environments with low traffic load or for mobile terminals close to the cell site.

However, there are several critical issues related to the use of wider transmission bandwidths in Wireless networks. Spectrum is often a scarce and expensive resource, and it may be difficult to find spectrum allocations of sufficient size to allow for every wideband transmission, especially at lower-frequency bands. The use of wider transmission and reception bandwidths has an impact on the complexity of the radio equipment, both at the base station and at the mobile terminal. As an example, a wider transmission bandwidth has a direct impact on the transmitter and the receiver sampling rates, and thus on the complexity and power consumption of digital-to-analog and analog-to-digital converters as well as front-end digital signal processing. RF components are also, in general, more complicated to design and more expensive to produce, the wider the bandwidth they are to handle.

*Modify frequency of clock that drives PLL*

Implemented on Atheros cards – programmable clock can generate 5, 10, 20, 40 MHz widths because the reference clock frequency used by the PLL determines the channel width. A phase-locked loop or phase lock loop (PLL) is a control system that generates a signal that has a fixed relation to the phase of a

"reference" signal. A phase-locked loop circuit responds to both the frequency and the phase of the input signals, automatically raising or lowering the frequency of a controlled oscillator until it is matched to the reference in both frequency and phase. A phase-locked loop is an example of a control system using negative feedback

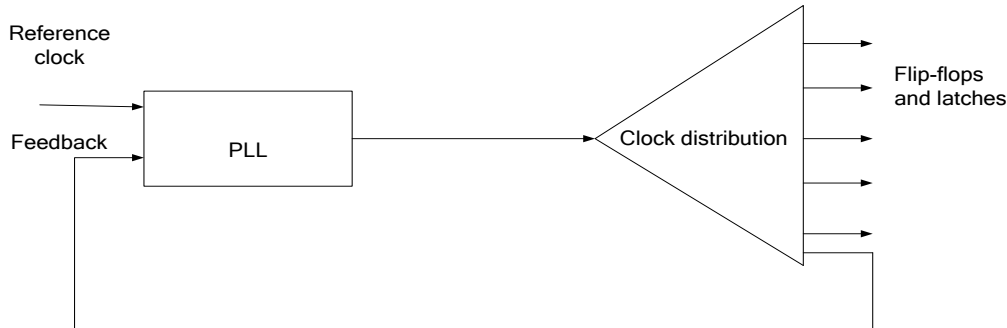


Figure 2.3: Clock distribution

Typically, the reference clock enters the chip and drives a phase locked loop (PLL), which then drives the system's clock distribution (figure2.3). The clock distribution is usually balanced so that the clock arrives at every end point simultaneously. One of those end points is the PLL's feedback input. The function of the PLL is to compare the distributed clock to the incoming reference clock, and vary the phase and frequency of its output until the reference and feedback clocks are phase and frequency matched

*Turn off certain subcarriers of OFDMA*

Transmission by means of OFDM can be seen as a kind of multi-carrier transmission. The basic characteristics of OFDM transmission, which distinguish it from a straight forward multi-carrier extension of a more narrowband transmission scheme as are, the use of a relatively large number of narrowband sub carriers, OFDM transmission may imply that several hundred sub carriers are transmitted over the same radio link to the same receiver[22,23,24,]

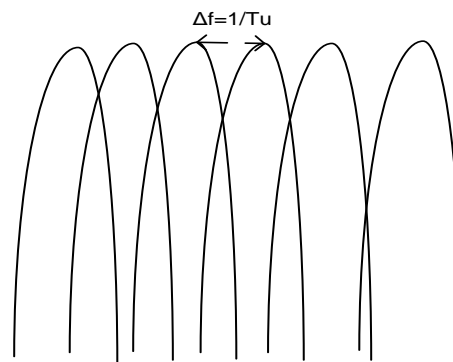


Figure 2.4: OFDM subcarrier spacing

Tight frequency-domain packing of the subcarriers with a subcarrier spacing  $f = 1/T_u$ , (figure 2.4), where  $T_u$  is the per-subcarrier modulation-symbol time. The subcarrier spacing is thus equal to the per-subcarrier modulation rate  $1/T_u$ . The number of OFDM subcarriers can range from less than one hundred to several thousand, with the subcarrier spacing ranging from several hundred kHz down to a few kHz. That subcarrier spacing to use depends on what types of environments. The system is to operate in, including such aspects as the maximum expected radio channel frequency selectivity (maximum expected time

dispersion) and the maximum expected rate of channel variations (maximum expected Doppler spread). Once the subcarrier spacing has been selected, the number of subcarriers can be decided based on the assumed overall transmission bandwidth, taking into account acceptable out-of-band emission, etc..

The number of subcarriers depends on transmission bandwidth, with in the order of 600 subcarriers in case of operation in a 10MHz spectrum allocation and correspondingly fewer/more subcarriers in case of smaller/larger overall transmission bandwidths.

## II. THE POSSIBLE PROBLEMS

The transmitting frequency of the nodes in wireless LAN communications at the moment is 20 MHz. The width of a wireless communication channel is one of the most important parameters in wireless communication. It's been surprising that fixed channel widths are taken for granted in virtually all wireless networking research. Thereby each AP is assigned a fixed width of 20 MHz channel and the neighboring APs are placed on orthogonal frequencies. For the network whose traffic is uniformly distributed, there is an increase in capacity as well as a reduction in interference [25]. Therefore the following are main problems in wireless LAN communication which we need to investigate if we allow adapting channel with.

### a) Fairness problem among users

Fixed channel width has many problems as the number of APs is few compared to the number of available channels. This causes the available spectrum

not fully utilized since each AP is entitled to only one channel. On the other hand, if the number of APs is large, two or more neighboring APs are inevitably assigned the same channel, which can create interference. Also, as the traffic requirement is different from users associated in one AP, it is a big problem to satisfy each and everyone with fixed channel bandwidth; therefore they will be unfairness among users to access the channel [26].

Imagine in case where you have for example 3 access points. First access point is associated to 10 users, second one associated to 4 users and last one associated to only 2 users, as we can see well that users associated to the first AP will suffer compared to others because of limited channel width. Therefore, there will be unfairness among users. To solve fairness problem, [33] proposed an intelligent association control to reduce load imbalance and unfair bandwidth allocation among users, associated with different APs. As shown in the figure 3.1

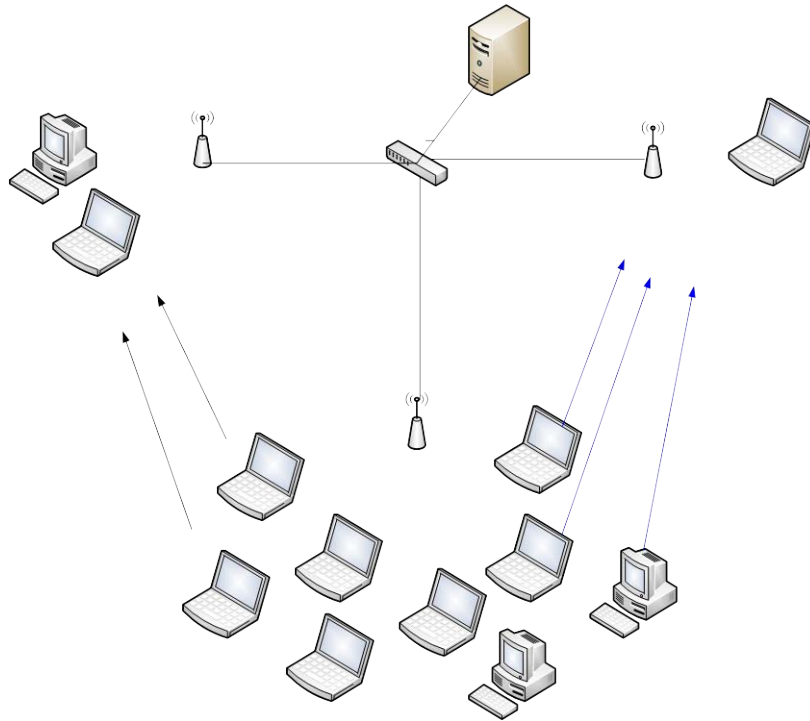


Figure 3.1: WLAN scenario discussion in [reference 33]

But their mechanism has shown some drawback for some clients connected to far APs. Those users suffer low SNR which leads to their lower data rate and low throughput. In Cell Breathing a load balancing mechanism was proposed to handle client congestion in WLAN. Also power management algorithms for controlling the coverage of APs were developed to handle dynamic changes in client workloads, just as solution to overcome the drawbacks mentioned above. But their algorithms don't always achieve good solution. Because transmission power control is practically

difficult to implement therefore problem of clients connected to far APs still persists. [27]

[28] Proposed a technique to improve the usage of wireless spectrum by using new channel assignment methods which are Dynamic channel re-use and weighted channel assignment where channel assignment problem is modeled as graph coloring problem. As shown in the figure 3.2

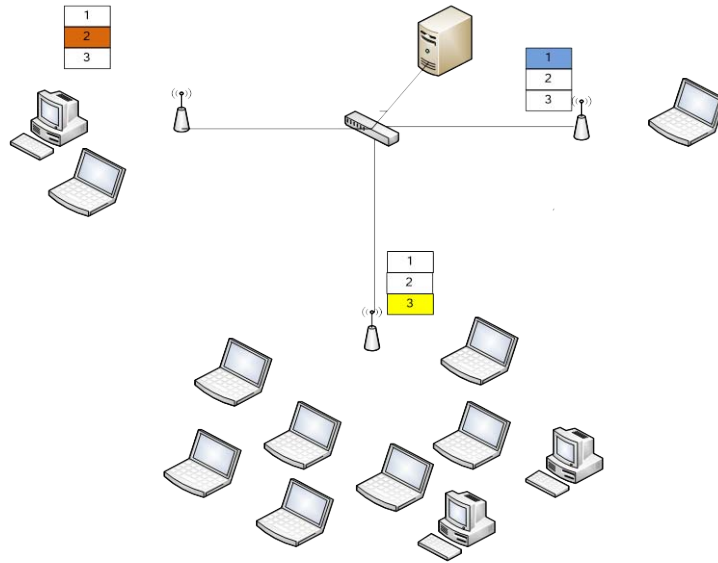


Figure 3.2: Dynamic channel reuse discussion in [reference 28]

This is indeed a nice idea but it has limited potential because an AP is still assigned to one channel only. After all proposed mechanism, in the fixed channel width there is no other choice as the channel is fixed to 20 MHz.

In fact the best mechanisms should assign more spectrums, where spectrum is needed. Therefore, in [20] adapting channel width is extensively studied, and proposed to be sufficient solution to provide fairness among users. By allocating more bandwidth to more loaded applications and less bandwidth to less loaded applications. That can be achieved by using OFDM transmission. The bandwidth of OFDM ( $BW$ ) =  $N_c \cdot \Delta f$ , where,  $N_c$  is number of subcarriers and  $\Delta f$  is carrier spacing. In our investigations  $\Delta f = 15$  KHz. And the number of subcarriers to generate different channel width is given bellow.

Table 3.1: Number of OFDM subcarriers for different channel width

Number of subcarriers	600	1200	2400
Channel width ( MHz)	10	20	40

Summary on the fairness problem, in the fixed channel structure presence of multiple users in WLAN creates a competition for access to the wireless channel. To be fair, node should have equal opportunity to win the contention, and gain an equal share of the wireless channel. However, the two goals in the design of a MAC protocol, namely maximizing wireless channel utilization and fair allocation of wireless channel bandwidth, are not always compatible with each other. Base station buffer size, wireless link interference, link asymmetry or hidden terminals etc. further exacerbate the fairness issue, sometimes even shutting off all flows

through a node or excessive collisions, making the default allocation of the medium by 802.11, below optimal.

Considering the different channel width will result in different performance even though the user can be guaranteed the spectrum according to its need, by using current MAC protocol which offer equal channel access opportunity, that can create fairness problem among nodes, due to different performance discussed above. But here if the MAC protocol is designed to assure fairness in terms of channel capacity, adapting channel width will be a solution to guarantee the fairness among users, because any user can get more resources according to its need. Therefore fairness may be achieved by controlling the contention window size for each station properly or assigning different priorities to different nodes.

b) *New hidden terminal problem*

By adapting channel width, different nodes hold different channel widths, which lead in showing them in different transmission ranges and interference range, consequently hiding some nodes from each others. To avoid hidden terminal problem for any node which it wants to transmit to AP, it will use RTS/CTS handshake before transmitting any frame.

i. *Concept of hidden terminal*

In WLAN, the Station cannot transmit and sense the channel at the same time, therefore it may happen that two stations transmit to the AP at the same time or another station may transmit to the AP, resulting in a collision, because two stations are hidden from each other and have a different view of the channel state (busy or idle) [29].



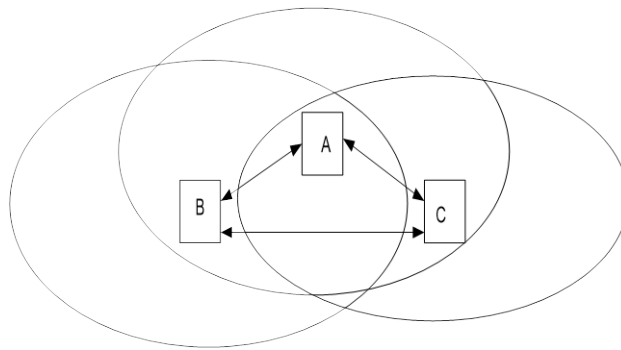


Figure 3.3: Example of hidden nodes

As shown in figure 3.3, node A can communicate with both B and C but B and C are hidden from each other. The collision can occur when those nodes want to communicate at the same time and same destination. Hidden terminal problem may be caused by signal fading and attenuation caused by static

obstruction. It can also be caused by transmission range. One of the best methods to overcome hidden terminal problem, is the use of the request to send and clear to send (RTS/CTS) incorporated into IEEE 802.11. [30, 31]

ii. *RTS/CTS to overcome hidden terminal problem*

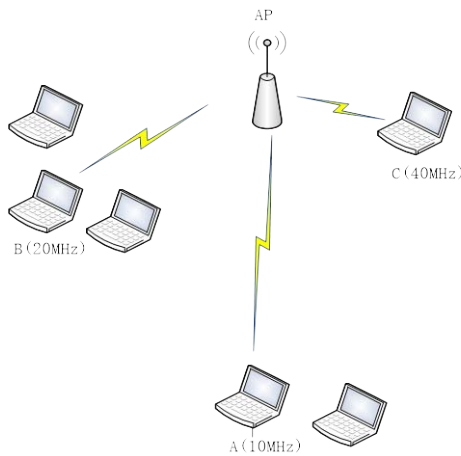


Figure 3.4: Nodes with different channel width

Consider Figure3.4 where the nodes transmit with different channel width. Those nodes are within a range of an Access Point. Due to their different channel width requirements, they intend to access the AP in different manner [32]. For example node B may be communicating with AP, because node A is not in the same range of B, it listens and hears no traffic in that case it may think that the medium is free of

transmission. Then starting to inquire the channel, since B is already transmitting collision may occur, Because B is hidden from A. this problem known as Hidden terminal problem. To avoid such situation we need to enable RTS/CTS on a particular station. So that while a node is initiating the RTS, others are hold off from accessing the medium RTS/CTS scheme is shown with a figure 3.7

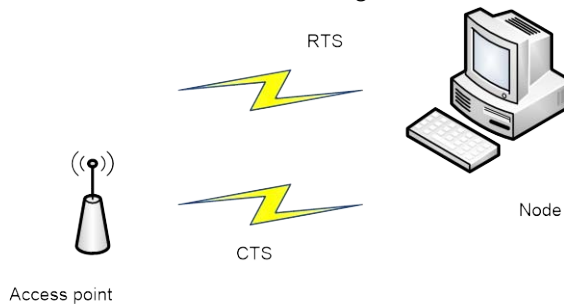


Figure 3.5: RTS/CTS scheme



Because overhead of RTS/CTS packets increases WLAN delay, the Threshold RT frame should be provided to determine when RTS/CTS handshaking mechanism takes place. Before communication .DCF MAC is designed to solve the hidden terminal problem

here we set RTS threshold and compare it with the frame length, if the length of a data frame is greater than a preset RTS threshold. After a backoff procedure the station sends an RTS, reserving the channel for the following data frame, figure 3.6

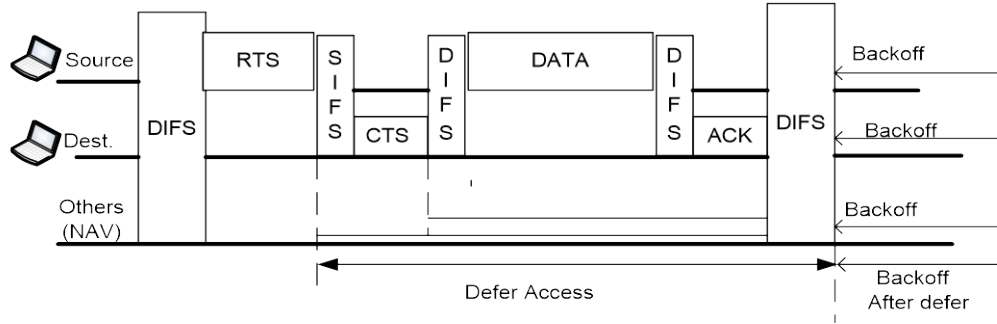


Figure 3.6: 4 way handshaking schemes

When RTS frame is detected by a receiver, after SIFS time period, the receiver responds with a CTS frame. All stations in the network hearing the sender or receiver set their Network Allocation vector (NAVs) to that value. After DIFS time period, sender transmits its data to the receiver node. If data received correctly after DIFS time period, receiver sends an Acknowledgement to the sender by data received confirmation.

In this situation, nodes are assured of having no collision; therefore, hidden terminal problem is avoided. [34]

With variable channel width nodes will be having different capacity which makes them to be in different ranges (proved by numerical analysis) that will give more chance the nodes to be hidden from each other compare to the fixed channel width where the nodes range is not much different. Therefore in designing MAC protocol for evaluating performance of suggested scenario, care should be taken for the use of RTS /CTS, due to higher communication range of some nodes which require low throughput.

*Analysis relationship among power, channel width and transmission distance*

In a typical wireless communication environment, multiple propagation paths often exist from a transmitter to a receiver due to scattering by different objects. Signal copies following different paths can undergo different attenuation, distortions, delays and phase shifts. At the receiver side, these different signal copies may add constructively or destructively. This leads to the so-called multipath or small-scale fading. Fading manifests as significant fluctuation in signal-to-noise ratio (SNR), bit error rate (BER) increase, more frequency packet loss and link failure. The SNR is computed from the power of the received signal and the noise power [35, 36, 37, 38]

Pathloss describes the loss in power as the radio signal propagates in space. In any real channel,

signals attenuate as they propagate. For a radio wave transmitted by a point source in free space, the loss in power, known as pathloss, is given by

$$L = \left(\frac{4\pi d}{\lambda}\right)^2 \tag{3.1}$$

Where  $\lambda$  is the wavelength of the signal and  $d$  is the distance between the source and the receiver. The power of the signal decays as the square of the distance Hence the impact of pathloss exponent parameter was evaluated and found that the communication distance between sender and receiver to be different with different pathloss exponent Signal coverage is influenced by a variety of factors, like radio frequency of operation and terrain. The core of the signal coverage calculations for any environment is path-loss model which relates to loss of signal strength to distance between terminals. Using path loss modals, radio engineers calculate the coverage area of wireless base stations and access points as well as maximum distance between two terminals.

Let  $P_t$ , be transmitted power, after distance  $d$  in meters, the signal strength will be proportional to  $P_t d^{-\alpha}$  where  $\alpha$  is a path loss gradient, which is equal to two in free space ( $\alpha = 2$ )

Therefore relationship between the transmitted power  $P_t$  and received power  $P_r$  in free space is given by

$$\frac{P_r}{P_t} = G_t G_r \left(\frac{\lambda}{4\pi d}\right)^2 \tag{3.2}$$

Where,  $G_t$ ,  $G_r$  are transmitter and receiver Gain,  $d =$  distance between transmitter and receiver in our case can be considered as Distance between node and AP.  $\lambda = (c/f)$  is the wave length of the carrier. From (3.2)

$$P_t = \frac{P_r}{G_r G_t \left(\frac{\lambda}{4\pi d}\right)^2} \quad (3.3)$$

Assume other parameters to be constant; we can say that  $P_t/f^2 \equiv k d^2$

$$(d)^n = \frac{P_t}{P_r} G_t G_r \left(\frac{\lambda}{4\pi}\right)^\alpha \quad (3.4)$$

Also from equation (3.2) As we know  $\lambda = \frac{c}{f}$ , hence in the fixed power if the frequency varies  $d$  also vary.

For bandwidth greater than 10 KHz, for any two channel width  $B_2$  and  $B_1$ , the required dynamic range ration in db is

$$10 \log (B_2/B_1) \quad (3.5)$$

c) Numerical analysis Plan and purpose

We intend to investigate by numerical analysis using MatLab tool the performance of WLAN given on the figure3.7

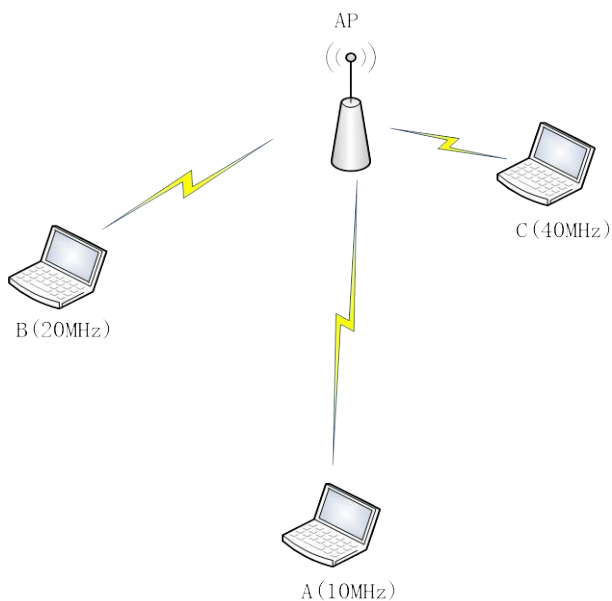


Figure 3.7: Nodes with different channel width

In this scenario topology we suggested to use 3 nodes of different channel width with fixed power. Let us assume that node A transmits at 10 MHz, Node B with 20 MHz and Node C with 40 MHz channel width. According to the study carried out in paper [20], we can increase transmission range by reducing channel width or in other words node A has higher transmission range compared to Node B, and node B has higher transmission range as compared to node C. Therefore, those different nodes hold different bandwidth which leads to fairness problem and hidden terminal problem due to interference and transmission range. Here

different policies and different protocols should be adapted.

By investigating the performance of figure 3.7, with fixed power, we can see that all stations are in the communication range of access point (AP) and due to the different channel width all nodes may not be in the same carrier sense range. Therefore, the traffic only exists on 2 directions: from AP to stations and from stations to AP. According to the node's locations, AP always can sense the traffic from stations and the traffic from AP to stations will be sensed by all the stations. Hence all Analysis will focus on traffic from stations to the AP. Because all nodes are in the transmission range of AP therefore no problem of hidden terminal or interference to the traffic from AP to stations.

d) Impact of channel width on distance

We investigate and analyze the topology given in the figure3.7 which is infrastructure base service set for each node transmits with different channel width in the fixed power transmission, that is for example node "A", with 10MHz , node "B" with 20MHz, and node "C" with 40MHz, and the distance is measured from the each node to the access point. The investigation is intended to see that whether the distance is function of channel width, but the following consideration is taken in place to make sure that the collision is avoided.

Using path loss modals, we can calculate the coverage area of wireless base stations and access points as well as maximum distance between two terminals.

$$L = \left(\frac{4\pi d}{\lambda}\right)^2 \quad (4.1)$$

$$(d)^n = \frac{P_t}{P_r} G_t G_r \left(\frac{\lambda}{4\pi}\right)^\alpha \quad (4.2)$$

For any two channel width  $B_2$  and  $B_1$  the required dynamic range ration in dB is given as

$$10 \log_{10} \left(\frac{B_2}{B_1}\right) \quad (4.3)$$

The dynamic range depends on the bandwidth and the centre frequency on our investigation all adapted channel width have the same centre frequency (2.412GHz)

Data Analysis

For this experiment power transmission is fixed to 1mW and  $\alpha = 4$  and peak level in db attenuation for 20 MHz channel width is given to 80 db as required in practice.

$$A = 10 \log_{10} \frac{P_s}{P_r} = 10\alpha \log_{10} d \quad (4.4)$$

Where:

- A is maximum range in db attenuation,
- $P_s$  is power sent
- $P_r$  is power received.
- $\alpha$  is path-loss exponent and d the distance from AP to node.

- d: is a distance in meter

In this case  $P_s$  is fixed to 1mW, therefore from the results given on table 5.2, signal strength Vs Distance is plotted as in the figure 4.2

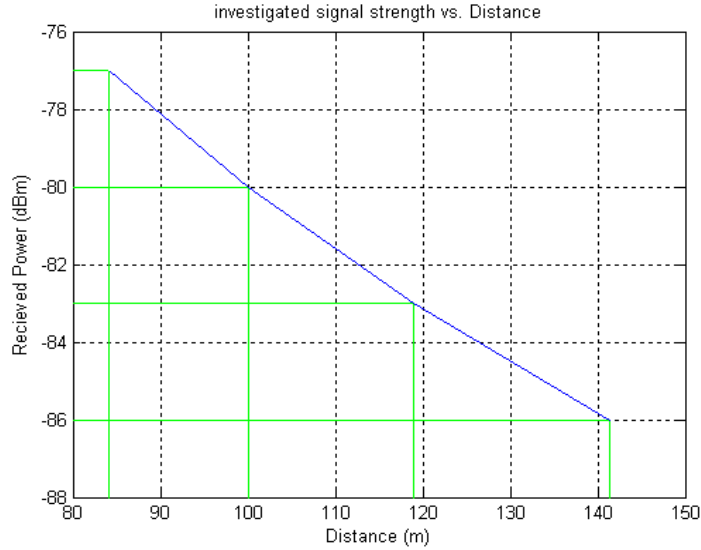


Figure 4.2: Signal strength Vs. Distance

On figure 4.2, more the node communicates to the higher distance, more received power reduced, therefore the node required to transmit with lower channel width without any interruption. 120m is found to be the maximum transmission distance achieved by a

node which transmits with 10MHz channel width with minimum signal strength.

The following figure shows the relationship between transmission distance and channel width.

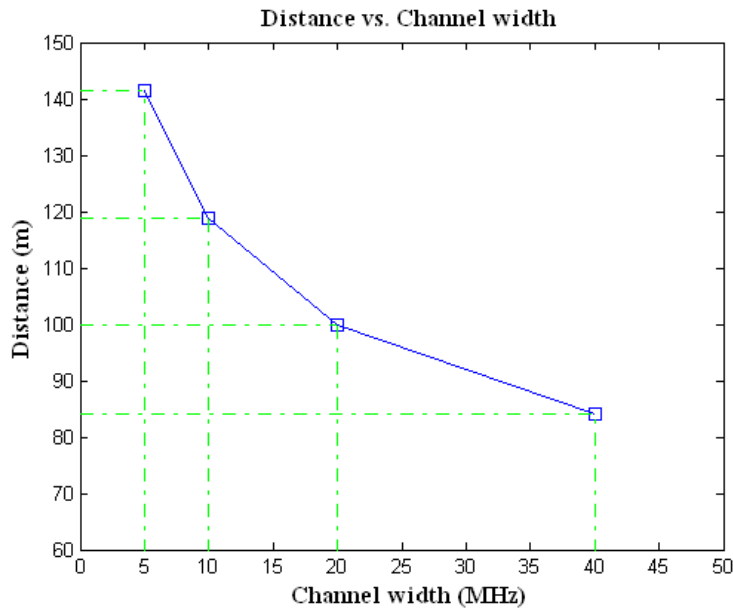


Figure 4.3: Distance vs. Channel width

Figure 4.3, transmission distance increases by reducing channel width. For example for 40 MHz channel width, the transmission distance is found to be 82 meters, whereas for 10 MHz is approximately 120 m.

Hence, the channel width has big impact to the distance, when channel width reduces the distance transmission increases.

*Impact of Modulation on transmission distance*

To provide higher data rates within a given transmission bandwidth, we use higher order modulation that allowing for more bits of information to communicate per modulation symbol. Therefore we are investigating different symbol interval of OFDM modulation<sup>[39]</sup>.

$$\text{Nominal bandwidth of transmitted signal (B)} = M / N \cdot f_s \tag{4.5}$$

Where:

*M*: Modulation symbols from some modulation alphabet like QPSK, QAM etc.

*N*: bits size. = 2<sup>n</sup> and *f<sub>s</sub>* is a sampling frequency.

From (1) during transmission with OFDM modulation scheme, normal bandwidth of the

transmitted signal is proportional to modulation symbols per second (*M*).

If *M* is Higher, the bandwidth increased hence the transmission distance reduced.

Above figures show that the modulation used by the radio while transmitting has also a big impact on distance

$$A = 10 \log_{10} \frac{P_s}{P_r} = 10 \alpha \log_{10} d$$

We can investigate the impact of modulation with different cases of communication by applying different modulations. The data used to investigate the impact of modulation were taken on reference.<sup>[10]</sup>

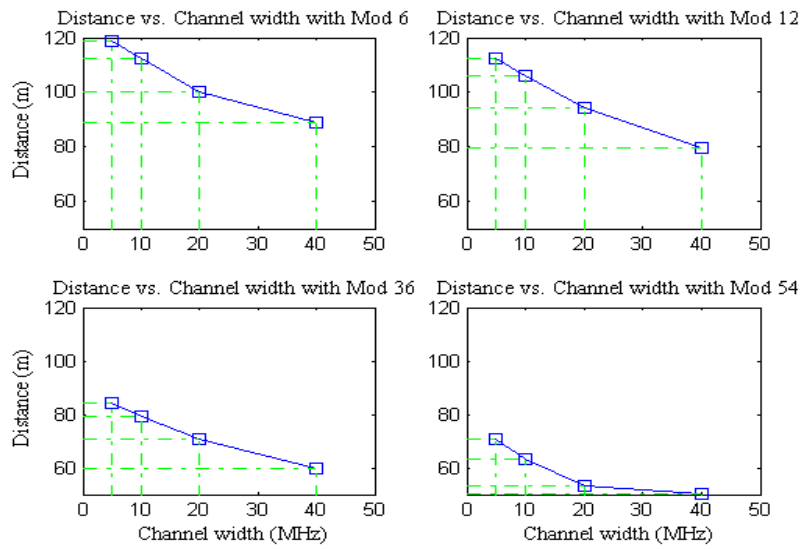


Figure 4.4: Distance Vs Channel width with different modulations

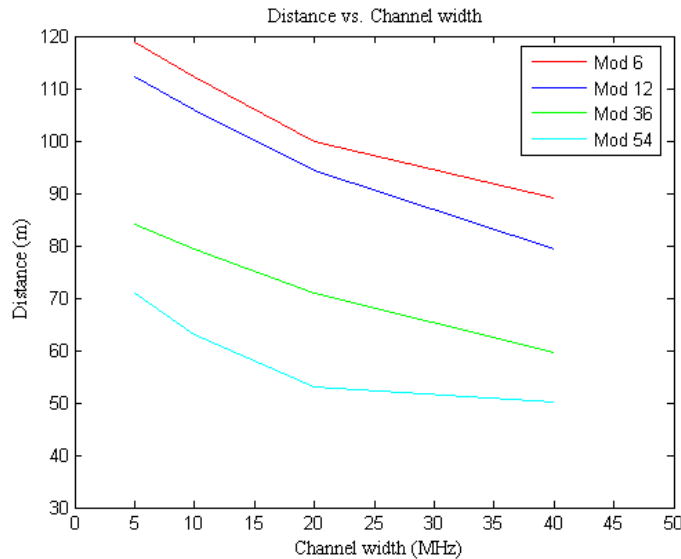


Figure 4.5: Comparison of distance with different modulations

On figure 4.5, we can see well that lower modulation provide more range compare to others. Therefore if you need to reach at higher distance by transmitting with low channel width (example 10 MHz for our proposed model) it is better to transmit with lower modulation (modulation 6). To maximize the performance of our topology OFDM modulation 6 is preferred.

### III. CONCLUSION

This study focused on the performance of WLAN of different nodes from which transmit the information with different channel width. We assumed that AP can adaptively change its channel width according to the user requirements. We discussed two major problems which arise to reduce the performance of WLAN: which are fairness and new hidden terminal problem. The following Observations were made from the Analysis obtained by MatLab simulating tool:

*Adapting channel width offers rich possibilities for improving system performance.*

Because, it increases the range of communication, providing the users with the required spectrum, which offers a natural way to both improve flow fairness and balance the load across the nodes. in our investigation we found that by transmitting with channel width of 5 MHz, we can still access the channel and communicate with an AP with required signal strength, i.e. a kind of improvement in fairness among users, because every user can be allocated the spectrum according to his requirement, which is practically impossible with naturally fixed channel width of 20 MHz, because maximum distance it can offer is not more than 100m (figure 4.3) and access for the nodes at higher distances suffers.

*Increase in channel width increases the throughput for investigated scenario*

The whole throughput found is approximately 20 MHz, which is near to 25MHz found by others, which consequently improves the fairness. Because modulation used in the transmission has an impact on distance, it is found that low modulation can be used to maximize transmission distance in case of low throughput. For new hidden terminal problem we purposed to use RTS/ CTS incorporated in MAC protocol, which we put on future work to improve it according to the scenario proposed.

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## Efficient Handoff for QoS Enhancement in Heterogeneous Wireless Networks (UMTS/WLAN Interworking)

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**Abstract-** Today's Wireless Communications technologies prove us that wireless communications will in the long run be composed of different communication networks as a way to benefit from each other. This can however be achieved from cellular networks and wireless local area networks that show some compatible characteristics that enable them be integrated. Scenarios typically behind these integrations is the UMTS and WLAN interworking where UMTS network is known for its wide area of coverage and nearly roaming however, known for lack of enough data rate. This is contrary with WLAN which is known for high data rate and cheaper compared to UMTS. WLAN however has a small area of coverage and lacks roaming. This in regard brings the idea that the two different networks being integrated could provide the means for mobile users to be gratified with a supported coverage and quality at anywhere and anytime with seamless access to internet.

**Keywords:** cellular networks, 3G (UMTS), 802.11 WLAN, heterogeneous wireless networks, handoff, QoS enhancement, mobility management.

**GJCST-E Classification:** C.2.1



EFFICIENTHANDOFFFORQOSENHANCEMENTINHETEROGENEOUSWIRELESSNETWORKSUMTSLANINTERWORKING

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# Efficient Handoff for QoS Enhancement in Heterogeneous Wireless Networks (UMTS/WLAN Interworking)

Alabi Peter Akubo

**Abstract-** Today's Wireless Communications technologies prove us that wireless communications will in the long run be composed of different communication networks as a way to benefit from each other. This can however be achieved from cellular networks and wireless local area networks that show some compatible characteristics that enable them be integrated. Scenarios typically behind these integrations is the UMTS and WLAN interworking where UMTS network is known for its wide area of coverage and nearly roaming however, known for lack of enough data rate. This is contrary with WLAN which is known for high data rate and cheaper compared to UMTS. WLAN however has a small area of coverage and lacks roaming. This in regard brings the idea that the two different networks being integrated could provide the means for mobile users to be gratified with a supported coverage and quality at anywhere and anytime with seamless access to internet.

Due to different behaviors of these integrated networks however, some difficult challenges such as Quality of Service may be degraded during network changes referred to as vertical handoff for integrated UMTS and WLAN networks. For QoS to be achieved therefore, handoff in such networks must be good. In addition, mobility management could also be in position to assure of connection especially when the user is roaming in heterogeneous wireless networks. In order to minimize QoS degradation, mobility protocols such as MIP (IPv4 and IPv6), mSCTP, SIP have been studied to verify and evaluate how they are affected when Real-time applications such as Video Conferencing and Non-real-time applications such as FTP are used in UMTS/WLAN interworking. The simulation results show the best mobility protocol to take into account when operating under UMTS/WLAN interworking scenario.

**Keywords:** cellular networks, 3G (UMTS), 802.11 WLAN, heterogeneous wireless networks, handoff, QoS enhancement, mobility management.

## I. INTRODUCTION

In the telecommunications environments presently with rapid growth in wireless technologies in relation to the user demands, force researchers to focus on how to provide better services to both subscribers and network operators. These services that we refer to as ubiquitous services, we mean connectivity anywhere and at anytime for mobile users and permanent internet as well as to corporate or private networks. This has

steered the communications industry developments in the past several years. This has actually evidenced in the quick growth and evolution of cellular networks and wireless local area networks. The Cellular networks such as third generation governed by Universal Mobile Telecommunication Systems (UMTS) and CDMA known for IS-95 A/B and CDMA2000 are known for their higher mobility and wider coverage but lower bandwidth that are still not enough for satisfaction of many data intensive applications. Wireless local area networks are oppositely known for their high speed data support but with small coverage area and limited mobility.

It is in this regard that the integration of UMTS and 802.11 WLAN offers benefit to both operators as well as to subscribers. This wireless communications environment is referred to as Heterogeneous wireless Networks (HWNs). However, an important and major problem is how to provide a reliable or guaranteed end-to-end quality of service (QoS) in a scalable behavior with seamless roaming in Heterogeneous Wireless Networks (HWNs) for multimedia service. In heterogeneous networks, according to the diverse characteristics and advantages, we could handoff to a new wireless communication system with better QoS provisioning by received signals. This enhances the performance of the networks and keeps the connection stable. Between Cellular mobile (UMTS) and WLAN networks, from previous researches, several couplings have been researched on. Consider figure 1 below where the two networks can mostly be integrated in tight coupling, loose coupling, or open coupling network arrangements. In the tight coupling approach of which is actually the focus of this thesis, the 802.11 WLAN coverage area appears like another SGSN coverage area to the UMTS CN. For security reasons as well as seamless handoff between WLAN and UMTS tight coupling is the only and best solution as UMTS compared to loosely coupled, peer and hybrid coupled and this can also be depicted in [1], [2].

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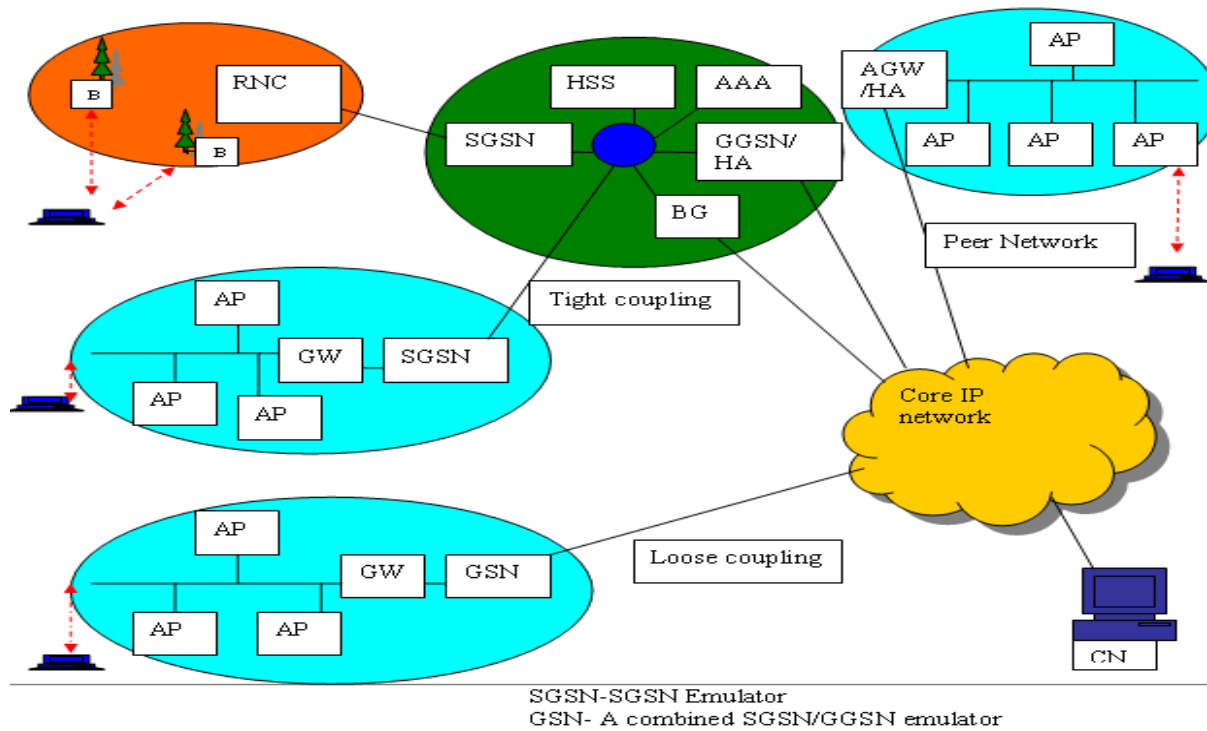


Figure 1: UMTS/802.11 WLAN general architecture

Contrary with the loosely coupled approach, the gateway directly connects the WLANs to the Internet backbone, and there is no direct link between the WLANs and the cellular core network. Due to network heterogeneity, the handoff between the cellular network and WLANs is referred to as vertical handoff, in contrast with horizontal handoff between base stations (BSs) or access points (APs) within a homogeneous wireless network.

Under the QoS considerations, the vertical handoff decision algorithm is an important aspect in cellular (UMTS)/WLAN interworking and is quite different from that in horizontal handoff. Additionally, mobility management is also an important aspect for ensuring that the user could stay connected or even reach better transmission capability when the mobile device changes the position. Handoff is a process of transferring a mobile device's communication from the old base station to a new one as this could also be discussed in [3]. The two (Vertical handoff and mobility management) being efficient can enhance the QoS in heterogeneous wireless networks.

#### a) Problem Statement

As we can observe from the trend of wireless communication networks and the market demand, we see that future generation wireless networks are expected to be the integration of heterogeneous wireless networks (HWNs) with Internet Protocol based infrastructure and support multiple bearer services. As a result, this will empower the service provider with the ability to capture advantages of different technologies to

support different needs of mobile users. However, a major problem is the means to provide end-to-end quality of service (QoS) guarantee with seamless roaming in HWNs for multimedia service in a method that is scalable. Actually many researches using various protocols on QoS provisioning have been studied, however QoS has still been a challenging problem in heterogeneous wireless networks. In addition to the above, seamless vertical handoff is also one of the major challenges in the next-generation heterogeneous wireless systems as good handoff decisions and implementations is one of the most important issues. Quality of Service provisioning depends on. Here, by seamless we mean that the handoff procedure should be transparent to applications in upper layers. In normal aspects we should expect two directional handoffs, one from WLAN to Cellular (UMTS) networks and vice versa. In order to achieve Quality of Service, issues for seamless handoff such as handoff metrics and handoff decision algorithms should be put under considerations and also mobility handling for maintaining on-going user connections. The impact of the above will be shown by performing simulation by using Optimal Network Simulator (OPNET).

#### b) Purpose of the research paper

As mobile communications technologies have evolved so rapidly even the number of mobile users and service providers has considerably increased. This being combined with many wireless LANs setup at hotspots in public areas like airports, conference halls, university campuses, hotels and cafes could

significantly benefit from the integrated local and cellular communication technologies. Thus interworking between cellular (UMTS) and WLAN networks has been a popular issue to utilize benefits of each system. However, to achieve this, it would be vital that proper handoff mechanisms be established to realize internetwork roaming.

Since Quality of Service in this integration (heterogeneous wireless networks) has to be highly considered, the main objective of this research is;

- To minimize the service quality decrease such as; longer handoff delay (packet end to end delay), decreased throughput and network disconnection through analyzing the best mobility protocol for UMTS/WLAN interworking.
- To provide clear techniques (an interworking architecture) how handoff can be performed.
- To propose a solution that can enhance service quality during handoffs in UMTS/WLAN interworking.

We understand that there are many problems that do exist in such an interworking architecture however the focus of this research is to analyze the best mobility protocol that will provide efficient handoff which can finally support continuous services to the users.

## II. LITERATURE REVIEW

In the past several years, wireless communications field with high speed networks and their respective wireless systems, seem to have been top hot topics of research in the society. With Cellular and WLAN networks' quick evolution and successful deployment widely have been the two promising ones in this area of communications. The primary objective of Cellular networks was high quality circuit switched voice service with wide area coverage and they have been well deployed worldwide. The Global System for Mobile communication (GSM) and IS-95 being second generation cellular networks were a revolution to digital from analog technology and were additionally enhanced by General Packet Radio Service known as 2.5 generation for packet switched low rate of up to 100Kbps data services. However, with high rate demand increase for services such as multimedia, third generation (3G) evolved as a solution with expectations to deliver 2Mbps maximum bit rate. Contrary to cellular networks, WLANs have shown their capability over local area coverage to provide higher rate at a cheaper cost. This can be evidenced by IEEE 802.11b WLAN Working in the license-exempt 2.4 GHz industrial scientific and medical (ISM) frequency band, offering a data rate up to 11 Mb/s, whereas 54 Mbps data rate is supported by IEEE 802.11a WLAN and European Telecommunications Standard Institute (ETSI) HIPERLAN/2 in the 5 GHz frequency band as this can be well seen and discussed more in [9, 10].

It is in this point of view that the complementary characteristics of 3G cellular systems with low rate but wide coverage and WLAN with high rate but limited coverage make it attractive to provide ubiquitous wireless access when these two technologies are integrated. The integration therefore, of the IEEE 802.11 wireless LANs (WLANs) and 3G networks such as UMTS and CDMA2000 networks becomes a direction and focus in providing wireless services where even mobile IP that needs to be supported by both 3G (GPRS or UMTS) and WLAN is put under consideration. The mobile IP allows a user to maintain the same IP address and maintains connections while roaming between IP networks. This can also be discussed more in [10], [11] and [12].

In [13] and [14], feasible interworking architectures have been suggested to integrate cellular networks and WLANs for next-generation wireless communications, purposely for increasing cellular networks and WLANs with high-rate data services and area of coverage respectively as are of categories such as tightly and loosely coupled as well as peer network approach and hybrid coupled which behaves like tightly in terms of mobility guarantees while users are moving or in need to change their access technologies. This is however discussed more in [15, 16].

### a) *Mobility Management in HWN*

Being one of the most important issues in mobile data networks, mobility management supports roaming users to benefit their services with mobile terminals through wireless networks progress. As a consequence of UMTS being integrated with WLAN, subscribers could be provided with better services. Due to the fact that UMTS is a telecommunication network and supports mobility whereas WLAN is data communication network with no mobility management, it will thus need mobility management functions and this could be achieved through integrating the two network technologies which would finally provide radio resource control functions to WLAN as well.

Terminal mobility happens to occur in three different kinds that include; terminal mobility with respect to user communications that is further divided into discrete and continuous mobility, terminal mobility with respect to change in network access and terminal mobility with respect to administrative domains as this can be well addressed in [17]. The strategy UMTS utilizes are of three-level location management that include; an MS being tracked at cell level during packet transmission session, at the UTRAN registration areas (URA) level during the idle period of an ongoing session, and at the RA level when the MS is not in any communication session. As regards the IEEE 802.11WLAN network can however be treated as a special URA in a special routing area (RA), within which, the 802.11 WLAN mobility management is adopted.



Mobility management is in [15] also addressed for three architectures that include; tightly and loosely coupled, where UMTS network is considered to be the master home network with roaming privileges to WLAN and peer networks whose assumption is that the user may be subscribed to either the UMTS or to the 802.11 WLAN operators.

#### b) *Handoff Strategies*

Handoff as has been defined in previous sections, in wireless networks can be classified into two types that are horizontal handoff that occurs when the mobile terminal (MT) is handed-over from the old base station (BS) to the new BS within the same network, and vertical handoff which occurs when the MT is handed-over from the old BS to the new BS in a different network. Furthermore, Vertical handoff is seen to be classified into upward and downward vertical handoff where by definition upward vertical handoff occurs when a handoff is performed from an underlay to an overlay network, and in simple terms it means from high data rate such as WLAN to low data rate such as UMTS networks and downward vertical handoff occurs from low data rate to high data rate networks. Since horizontal handoff occurs in same network, vertical handoff appears a challenge because it occurs in different network technologies that may even happen to have some different characteristics despite their compatibility. Mobility protocols in support after vertical handoff can be used for mobility management purposes. Handoff will in details discussed in later chapters however is also discussed in [7], [18] and [19].

#### c) *Quality of Service (QoS) Strategies*

Quality of Service is an important issue to be put under consideration in wireless communications. With Quality of Service provisioning strategies in traditional cellular networks, resource allocation plays an essential role effectively to each MS during its traffic lifetime and efficiently utilizing scarce radio resources. Being known for lack of good QoS, WLAN integrated with cellular networks (3G/WLAN), much more challenge to achieve QoS and efficient resource utilization is expected due to the nature of heterogeneous wireless networks (3G [UMTS] and WLAN) in addition to the limited QoS support in WLANs. The study of how seamless handoff in terms of voice, data and multimedia becomes possible and how QoS can be mapped and guaranteed is highly needed and put under much emphasis. As [10] guides us, this is however done with the emerging IEEE 802.11e standard in the sense that WLANs aims at provisioning QoS in a relative sense, which is similar to and can be mapped smoothly to the relative QoS provided by the DiffServ described more in [4]. Therefore, the fine QoS provisioning in cellular networks and the relatively weak QoS support capability of WLANs need to be taken into account for cellular/WLAN interworking.

#### d) *Authentication and Security Strategies*

Authentication and Security such as billing, service continuity and authentication delay are still challenging problems that should be considered as far as integration of 3G and WLAN networks is concerned. The UMTS Authentication and Key Agreement (AKA) discussed in [20] have one drawback which is the need of several message rounds to complete its procedure. This may cause large authentication latency especially when interworking and since the 3G core network is far away from the 802.11 WLAN network, the authentication latency will obviously increase and this is unfavorable for real-time applications especially. Cheng et al. mentioned the identity privacy problem as seen in [20]. They went further in that the WLAN station must pass through the WLAN access control procedure and perform a signaling procedure with 3G (UMTS) core networks. Regardless of roaming or not they proposed a scheme that a user performs authentication and authorization via 3G radio interface. In order to reduce the message round, another researcher, Lin et al. proposed a one-pass authentication procedure for 3GPP IP multimedia core network subsystem (IMS). In addition, Tseng et al. proposed an efficient authentication protocol which adopts the hash-chain technique that happens to include three components that are; authentication server of 3G network (3G-AS), authentication server of WLAN (WLAN-AS), and mobile terminal (MT) which has dual interfaces to the connection with UMTS or WLAN. Authentication and security of this integration is in details discussed in [20]. In addition to the above, joint call admission control (JCAC) algorithm, which is one of the radio resource management algorithms for minimizing call blocking probability in heterogeneous wireless networks and QoS guaranteed requirements is also discussed in [21].

### III. CELLULAR NETWORKS

A cellular communications network has achieved popularity and has experienced explosive growth in the past two decades and this has been evidenced by the current usage of cellular phones that amounts to millions of people around the world. Cellular phones allow and enable a person or user to make or receive a call from almost anywhere. Likewise, while on the move, a person is allowed to continue the phone conversation. Cellular communications is supported by an infrastructure called a cellular network, which integrates cellular phones into the public switched telephone network. A cellular network is a radio network made up of a number of radio cells each served by a fixed transmitter, known as a cell site or base station. Since the area of coverage is put under consideration in cellular networks, these cells are used to cover different areas in order to provide radio coverage over a wider area than the area of one cell. Through the above, they

serve a number of advantages such as increased capacity, reduced power usage as well as better coverage.

There are requirements for succeeding a cellular network and the prominent one is for it to have developed a standardized method for each distributed station to distinguish the signal emanating from its own transmitter from the signals received from other transmitters. At present, there are two standardized solutions to this issue, one being frequency division multiple access (FDMA) that works by using varying frequencies for each neighboring cell and the other is code division multiple access (CDMA).

In addition, own other methods of multiplexing that include; polarization division multiple access (PDMA) and time division multiple access (TDMA). These however cannot be used to separate signals from one cell to the next since the effects of both vary with position and this would make signal separation practically impossible.

In this chapter, however discuss some GSM, GPRS and UMTS concepts that will facilitate my approach to integrating UMTS technologies with WLAN with specific interest being focused on the handoff mechanisms will briefly be addressed. Otherwise more of cellular networks are discussed in [22] and [23].

#### a) *Basic Cellular Network Concepts*

In the field of communications we find multiple concepts behind cellular networks such as cellular mobile phones that include the mechanisms under which cellular phones are connected by radio network towers. The cellular mobile radio network simple structure consists of the mobile switching centre (MSC), radio base station (BS), and public switched telephone network (PSTN).

A cellular network provides cell phones or MSs, to use a more general term, with wireless access to the PSTN. The service coverage area of a cellular network is divided into many smaller areas, referred to as cells, each of which is served by a base station (BS). The BS is fixed, and is connected to the mobile telephone switching office (MTSO), also known as the MSC. The MTSO is in charge of a cluster of BSs and it is, in turn, connected to the PSTN. The GSM system network is actually based on this network. For telephone users to get the desired services, requirements such as mobility management, registration and call setup as well as handoffs must be performed by this network. This will in the end enable MSs communicate with another and even wired line phones in the PSTN with wireless link between MS and BS. Both BS and MS are equipped with a transceiver. The link from an MS to the BS is called an uplink whereas that from BS to the MS is downlink. The cell system allow channel re-use, centralized control and increased system capacity with the capacity of the cell depending on the reuse factor

which is also influenced by the signal-to-interference ratio (SIR). In order to avoid the cause of co-channel interference, the group of frequencies cannot be reused in adjacent cells however can be reused in other cells. The advantage of reduced power usage that results in BSs with low transmission power, help minimize interference caused by fading due to mobility and scattering due to reflecting surfaces.  $D$ , a reuse distance, is calculated as

$$D = R \sqrt{3N}$$

$N$  is the number of cells per cluster whereas  $R$  is the radius of the cell. Cells radius vary where some ranges to 1 km others up to 30 km. The cells however could be of different shapes that include hexagonal, circular or some other undefined irregular shapes. More about cellular concept are in [23].

#### b) *Cellular Networks Evolution Overview*

Cellular systems became popular because of radio-frequency reuse, which allows more cell phone users to be supported. The cellular concept was first used in the Advanced Mobile Phone Service (AMPS) developed by AT&T in the United States in early 1980s [23]. The original cellular telephone networks provided analog traffic channels that are now referred to as first-generation systems (1G). As a first generation of cellular systems, AMPS is an FDMA-based analog system. The 2G of cellular systems uses digital technologies. Two interim standards, based on CDMA (IS-95) and IS-136 based on TDMA, are used in the United States, and TDMA-based GSM is used in European countries. It is clear that the 3G of cellular systems will be CDMA-based. However, the GSM community is developing WCDMA to be backward compatible with GSM while the CDMA community tries to evolve CDMA into CDMA2000. Currently researchers are studying technologies for beyond 3G (B3G) or fourth generation (4G) networks.

The Cellular radio systems, implemented for the first time in AMPS, supports more users by allowing reuse of frequencies. AMPS transmits 3-kHz voice signal over 30-kHz channel using frequency modulation and is part of first generation (1G) cellular radio systems. The first-generation systems are voice-oriented analog cellular and cordless telephones. IS-41 was originally developed to support the operations with AMPS. However, as an analog system, AMPS does not support voice encryption. To overcome the limited capacity of AMPS, especially in large cities, D-AMPS (IS-54) was developed in the early 1990s (EIA/TIA, 1990). Specifically, in D-AMPS, the same AMPS allocation of frequency spectrum is used, and each channel is still 30 kHz wide. However, in D-AMPS, a 30-kHz channel can be shared by three users through the 2G TDMA digital technology. First-generation cellular networks, such as AMPS, quickly became highly popular, threatening to

swamp available capacity. Second-generation (2G) systems which are voice oriented digital cellular and personal communication service (PCS) systems and data oriented wireless WANs and LANs have been developed to provide higher quality signals, higher data rates for support of digital services, and greater capacity. It means that D-AMPS allows a service provider to migrate from the first-generation analog technology to the 2G digital technology on a gradual basis [23, 24].

Before the Global System for Mobile Communications (GSM) was developed in 1990 in Europe, the European countries used a number of incompatible first-generation cellular phone technologies. GSM, a 2G system that uses the TDMA digital technology, was therefore developed to solve the incompatibility problem of different first-generation systems in Europe. It is now widely deployed around the world including in the United States. The allocated spectrum is divided into multiple channels of 200 kHz using FDMA, and each 200- kHz channel is shared by as many as eight users using TDMA. One feature of GSM worth mentioning is the SIM card that can be inserted into a cellular phone to provide the owner's identity information. The subscriber identity module (SIM) is a portable device in the form of a smart card or plug-in module that stores the subscriber's identification number, the networks the subscriber is authorized to use, encryption keys, and other information specific to the subscriber. A cell phone without a SIM card inserted does not work. A SIM card can be inserted into any cell phone to make the phone usable. Whereas IS-54, IS-136, and GSM are all TDMA-based, IS-95 is CDMA-based (EIA/TIA, 1995) where each user in CDMA is assigned a unique code to encode the data to be transmitted. CDMA an alternative to TDMA for 2G uses channels that are 1.25 MHz wide, and is able to support up to 64 users with orthogonal codes.

With the evolution of third generation (3G) of cellular wireless communication networks, its aim was to develop an international standard that combines and gradually replaces 2G digital cellular, PCS, and mobile data services. Furthermore, 3G systems were expected to provide fairly high speed wireless communications to support multimedia, data, and video in addition to voice and increase the quality of the voice and capacity of the network as well. The 3G path adopted by the GSM community is first to general packet radio services (GPRS), then to enhanced data rates for global evolution (EDGE), and ultimately to WCDMA (Qualcomm CDMA Technologies). Currently GSM provides data services of 9.6 Kbps using a single TDMA channel.

Finally, with the next generation referred to as beyond 3G or 4G is under research and will integrate wireless local area networks (LANS) such as IEEE 802.11 and Bluetooth with wide area cellular networks. The data transmission rate of 4G communications will

be much higher than 3G, at 20 to 100 Mbps in mobile mode. More information concerning evolution of cellular networks can however be depicted in [24].

#### c) *Global System for Mobile communication*

Originally from Groupe Spécial Mobile, Global System for Mobile communications (GSM) is a cellular network which in the world is the most popular standard for mobile phones. It is an ETSI standard for 2G pan-European digital cellular with ubiquity that makes international roaming very common between mobile phones operators, enabling subscribers to use their phones in many parts of the world. Its promoter, the GSM Association, estimates that 82% of the global mobile market uses the standard and is used by over 3 billion people across more than 212 countries and territories [22]. It uses TDMA as the air-link sharing technique and GMSK as its modulation scheme. In GSM, 8 users share each 200 KHz channel providing 25 KHz bandwidth for registered users. In GMSK, the signal to be modulated onto the carrier is first smoothed with a Gaussian low-pass filter prior to being fed to a frequency modulator, which greatly reduces the interference to neighboring channels known as adjacent channel interference. The ubiquity of the GSM standard has been an advantage to both consumers and also to network operators.

The GSM main architecture is divided into three general parts as [24] depicts:

- The mobile station (MS) with two elements; the first being mobile equipment (ME) which is a piece of hardware containing all the components that include speaker, microphone, keypad, and the radio modem needed for the implementation of the protocols to interface with the user and the air-interface to the BSS. The second element is the SIM which is a smart card issued at the subscription time identifying the user's address specifications and type of service.
- The Base Station Subsystem (BSS) that communicates with the user through the wireless air-interface and with the wired infrastructure through the wired protocols. The BSS lies between the MS and MSC. It often consists of one or more BTSs and a centralized BSC that manages and controls radio resources of the BTSs including frequency hopping, radio channel setup and handoff.
- Network and Switching Subsystem (NSS) responsible for the network operation and provides communications with other wired and wireless networks as well as support for registration and maintenance of the connection with the MSs. The NSS consists of MSC as a hardware part of the switch and four software elements that include visitor location register (VLR), home location register

(HLR), equipment identification register (EIR), and authentication center (AUC).

d) *General Packet Radio Service*

General Packet Radio Service (GPRS) network is an extension to the global system for mobile communication (GSM) network, which has been introduced to enable packet switched data services via the public land mobile network (PLMN). 2G cellular systems combined with GPRS are often described as 2.5G, that is, a technology between the second (2G) and third (3G) generations of mobile telephony. It additionally provides moderate speed data transfer, by using unused Time division multiple access (TDMA) channels in, GSM system. It was originally standardized by European Telecommunications Standards Institute (ETSI) as an enhancement of the circuit switched GSM network to support packet switched data services, but now is a standard by the 3rd Generation Partnership Project (3GPP). It provides a data rate from 56 up to 114 kb/s to users of GSM and IS-136 mobile phones. A

GPRS connection is established by reference to its Access Point Name (APN). The APN defines the services such as Wireless Application Protocol (WAP) access, Short Message Service (SMS), Multimedia Messaging Service (MMS), and for Internet communication services such as email and World Wide Web access. GPRS is a best-effort packet switched service, as opposed to circuit switching, where a certain Quality of Service (QoS) is guaranteed during the connection for non-mobile users [22]. Referring to the overall GPRS architecture below in Figure 3.0, we observe two main building blocks defined by; the core network and the base station subsystem (BSS). Both blocks are important to assess the performance of end-to-end packet data services. The BSS governs the GSM enhanced data rates for global evolution (EDGE) radio access network (GERAN) and provides the wireless interface to the MS. GPRS uses the physical air interface defined for GSM [25].

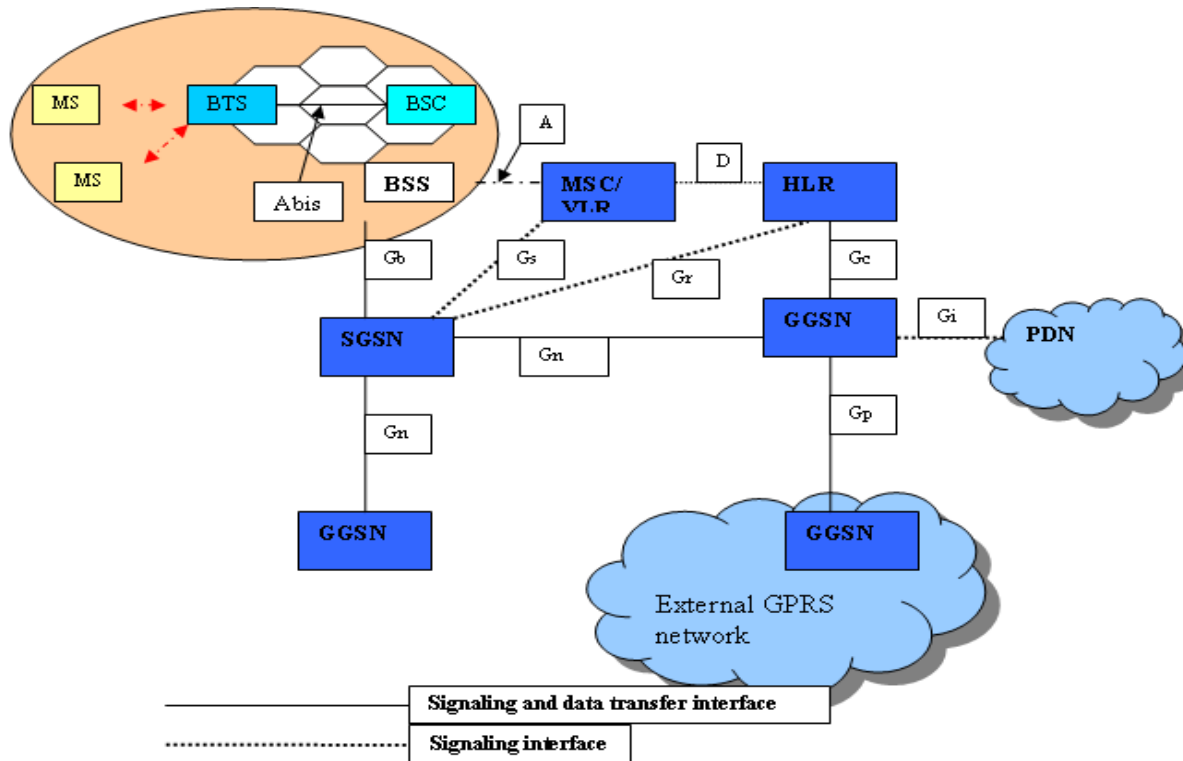


Figure 3: GPRS logical network architecture

The SGSN as clearly seen in the figure 3.0, functions as a packet switching MSC by delivering packets to MSs within its service area. It communicates with the HLR to obtain profile data of genuine GPRS subscribers.

The GGSN corresponds to the GMSC and is the final GPRS network exit node on route to other packet data networks (PDN) like the Internet or intranet. The GGSN's location directory has to be constantly updated about a MS's location by the SGSN. The SGSN and

GGSN interact with the MSC/VLR and HLR through Signaling System Number 7 (SS7) / IP gateway (SIG) connected to the IP backbone of the GPRS network.

*GPRS Mobility Management*

GPRS handles mobility management in same way as GSM does only that GPRS' MS may happens to be in three states that include idle, ready and standby unlike GSM with only ready or idle. Individual or several cells can be grouped in routing areas and every routing



area is served by one SGSN. A MS can move to ready state by attaching to the GPRS network and by activating a packet data protocol (PDP) context, which activates GPRS user profiles, including IP addresses and QoS parameters. The core network (CN) of the packet switched domain is essentially a cluster of routers and databases interconnected by different interfaces and protocols. Typically, the network interconnecting the CN devices is referred to as the packet data network (PDN). The Gb interface connects the BSS and the SGSN allowing the exchange of user data and signaling messages. The SGSN relays IP traffic originating from the MS to the gateway GPRS support node (GGSN) and vice versa. Furthermore, it collaborates with the HLR to manage mobility of the MSs. The GGSN provides interworking with external IP networks, such as the Internet. However detailed discussions can be obtained in [22], [23], [24] and [25].

e) *Universal Mobile Telecommunication System*

Universal Mobile Telecommunications System (UMTS) is one of the third-generation (3G) cell phone technologies, which is also being developed into a 4G technology. It represents an evolution in terms of services and data speeds from today's second generation (2G) mobile networks such as Global System for Mobile Communications (GSM) and the enhanced

2.5G mobile networks such as General Packet Radio Services (GPRS). Currently, the most common form of UMTS uses W-CDMA as the underlying air interface. It is standardized by the 3GPP, and is the European answer to the ITU IMT-2000 requirements for 3G cellular radio systems. To differentiate UMTS from competing network technologies, UMTS is sometimes marketed as 3GSM, emphasizing the combination of the 3G nature of the technology and the GSM standard which it was designed to succeed.

*UMTS Network architecture*

The network architecture of the UMTS system shown in figure 3.1 below consists of three parts that include The User Equipment (UE) domain, the UMTS Terrestrial Radio Access Network (UTRAN) domain and the Core Network (CN) domain.

The UE domain represents the equipment used by the user to access UMTS services while the UTRAN domain which is introduced for efficient radio resource control (RRC), together with the Core network (CN) domain, known as the infrastructure domain, consist of the physical nodes which perform the various functions required to terminate the radio interface and to support the telecommunication services requirements of the user.

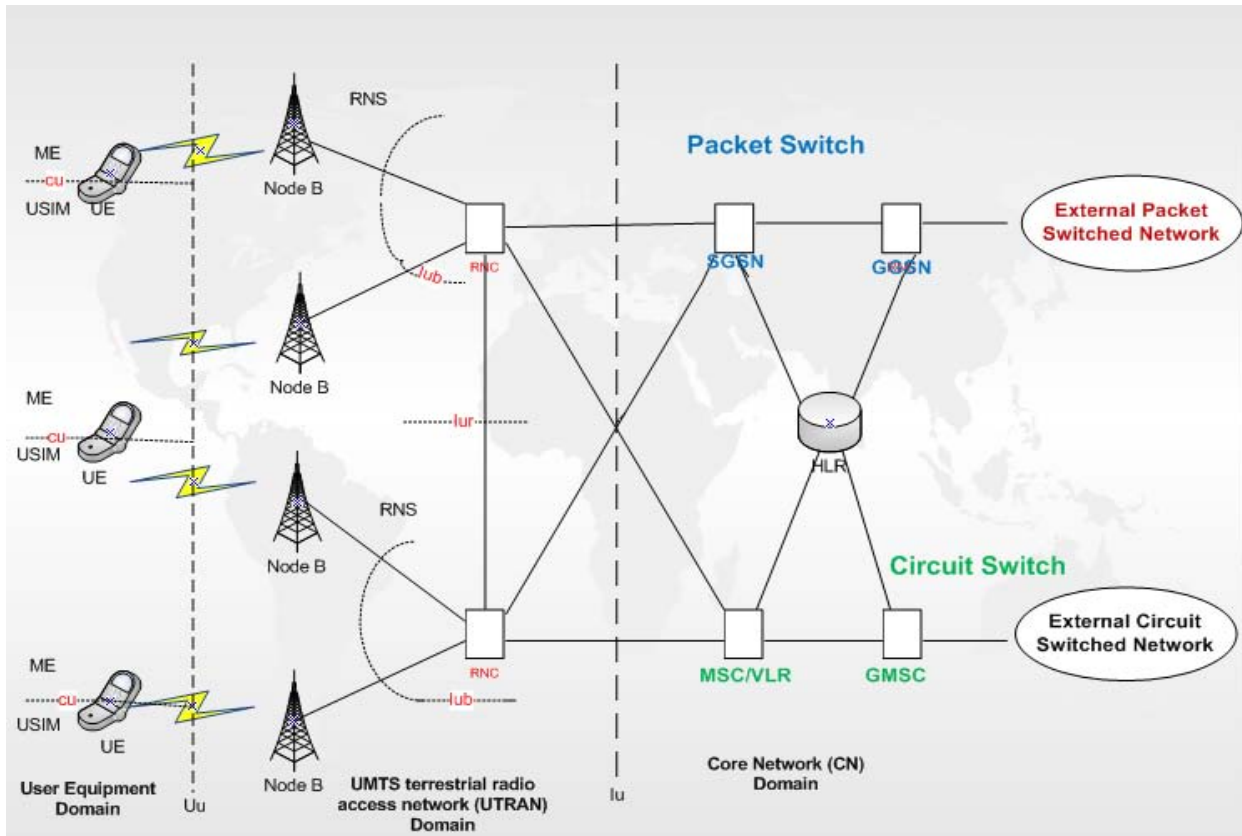


Figure 3.1: UMTS network architecture

The UE domain encompasses a variety of equipment types typically referred to as user equipment

with different levels of functionality such as cellular phones, personal digital assistants (PDAs), laptops etc.



It consists of two parts; The UMTS Subscriber Identity Module (USIM) which is a smartcard that contains user-specific information and the authentication keys that authenticates a user's access to a network, and the Mobile Equipment (ME) which is a radio terminal used for radio communication with the UTRAN domain over the Uu radio interface. The USIM is also physically incorporated into a SIM card and linked to the ME over an electrical interface at reference point Cu. The UTRAN domain that consists of one or more Radio Network Sub-systems (RNS) where each RNS consists of one or more Node B and one Radio Network Controller (RNC) handles all radio-related functionality. The Node B, also known as a Base Station and equivalent to the Base Transceiver Station (BTS) from GSM, converts the signals of the radio interface into a data stream and forwards it to the RNC over the Iub interface. It is also responsible for controlling data flow between UE and RNC, Channel coding and interleaving, rate adaptation, radio resource management and power control. Further more, in the opposite direction, it prepares incoming data from the RNC for transport over the radio interface. The RNC controls one or more Node Bs over the Iub interface and is responsible for the management of all the radio resources in the UTRAN. It is the central node in the UTRAN and equivalent to the Base Station Controller (BSC) from GSM. The RNC interfaces the CN domain over the Iu interface thus performs access point services from UTRAN to CN [26, 27, and 28].

The CN domain which is divided into a Packet Switched network (PS), a Circuit Switched network (CS) and a Home Location Register (HLR) is responsible for switching and routing calls and data connections between the UTRAN domain and external packet and circuit switched networks.

#### *Mobility management in UMTS*

In wireless networks where the terminal may be anywhere, a mechanism must be in existence to locate the terminal in order of delivering communication to it. All this is handled by mobility management where mobile communication systems like UMTS by definition are meant to handle mobility management. It involves two mechanisms that include; location management and handoff management. Location management is the mechanism a wireless network uses in keeping track of a user's location outside an active connection, whereas handoff management is the mechanism of handing over an active connection from one cell to another. Both mechanisms together are commonly referred to as Mobility management.

#### *Location Management*

Location management involves tracking of MS's location as it moves for the message voice or data delivery to it. Location management generally consists of three parts that include; location updates, paging, and location information disseminating. When an

incoming connection's transfer to an inactive user, the network must continuously be up-to-date with where the MS is. The location updates are messages that the user sends regarding its changing points of access to the fixed network, and is defined for both CS and PS services. In terms of CS services, the network is divided into Location Areas (LA) that consists of a number of cells between which the user can move without updating his location whereas with PS connections services, the UE will receive short data packets more frequently than is the case with CS connections. For the delivery of an incoming message to the user (MS), the network will have to page MS in such a group of cells and the paged terminal will respond through the point of access that is providing the coverage in its cell. Consequently, the location update for PS connections divides the network into even smaller areas called Routing Areas to limit the amount of paging as this can also be referenced in [24, 26].

#### *Handoff Management*

The basic idea behind handoff is to provide the continuous connection when moving among cells (from one cell to another). The handoff is actually realized by changing the radio channel. To forward an active connection from one cell to another, the network must perform a handoff. Therefore, handoff management involves issues and actions that are required to handle an ongoing connection when a mobile terminal moves from the coverage of one access point to another. Similar to location management, the handoff process is defined for both CS and PS services where in terms of CS services, handoffs can be implemented as soft handoffs, softer handoffs and hard handoffs [26]. During soft handoff user equipment is located in the coverage area of two or more different Node Bs. The user equipment simultaneously communicates with two or more Node Bs via two or more radio channels. If the received signal strength from the Node Bs in cells one and two differ by a maximum of an amount called the handoff margin during a certain period of time, a connection is also established to the Node B in cell two. However, when the received signal strength from Node B in cell one is smaller by a certain amount than that of the Node B in cell two, the connection to the first Node B in cell one is cleared. A received signal in Node B is routed to the RNC and compares the signal on the frame by frame basis. The best frame is selected for the next processing and the other frames are discarded [29].

A softer handoff is similar to soft handoff where transmission also runs in parallel over different sectors but of the same Node B. The main difference between these two handoffs resides in the sense that a UE is located in the coverage area of two sectors of one Node B. Also, UE initially communicates with Node B in sector one of cell one. The UE communicates with one Node B

via two radio channels. As the UE starts to move it also starts to receive a signal from the same Node B in the same cell one but from another sector (two). The signal from sector two is a reflected signal of the direct signal. This can happen if for example a large building is in the line of the direct signal and thus unintentionally relays the signal in another angle. If the received signal strength from sector one and two differ by a maximum of the handoff margin, a connection is established to sector two. When the received signal strength from

sector one is smaller than that of sector two, the connection from sector one is cleared and a softer handoff has taken place. Considering figures 3.2 and 3.3 below, in the downlink direction, the situation of combining the signals is same as in the case of soft handoff whereas in the uplink direction, the situation is different. The signal received in the Node B is not routed to the RNC; however, the combination of the signals is realized in this Node B's rake receiver.

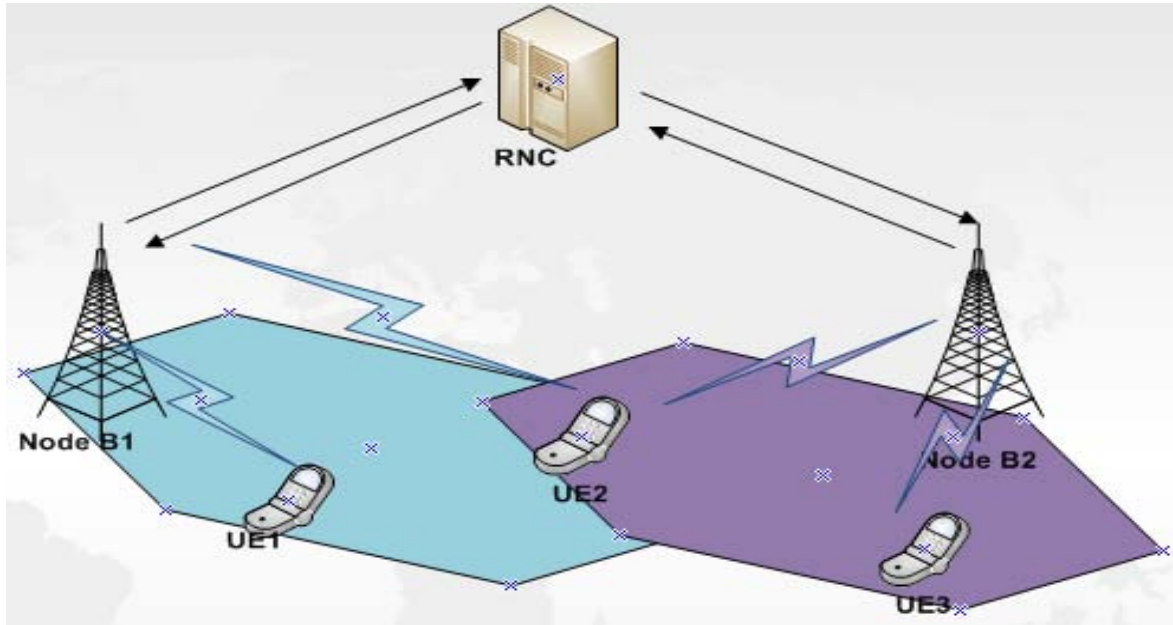


Figure 3.2: Soft handoff

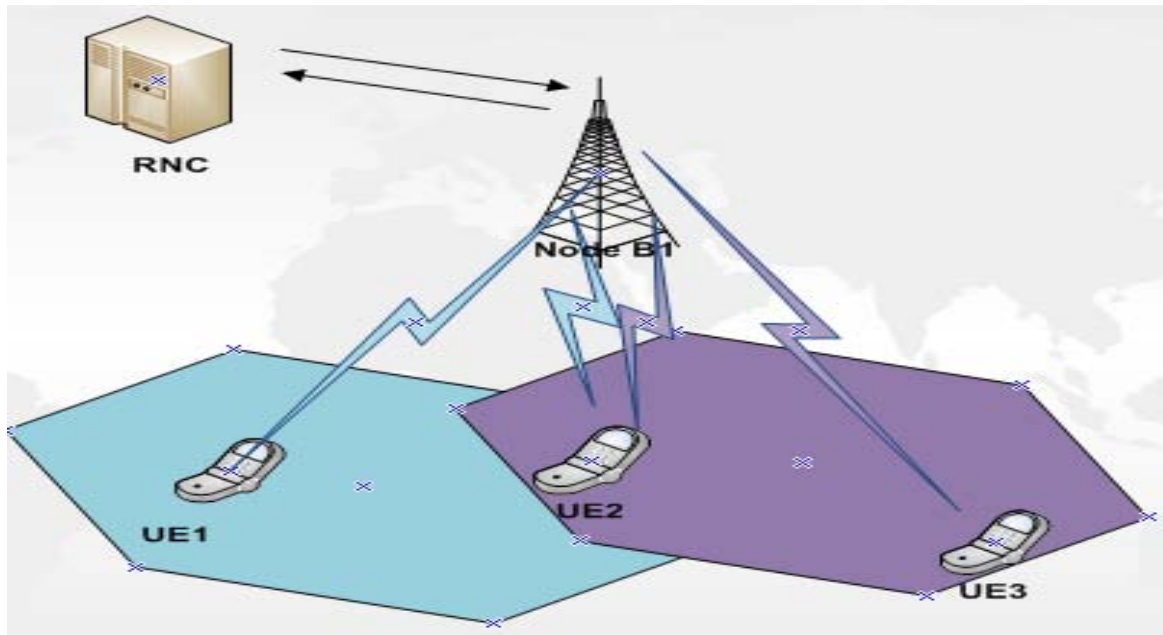


Figure 3.3: Softer handoff



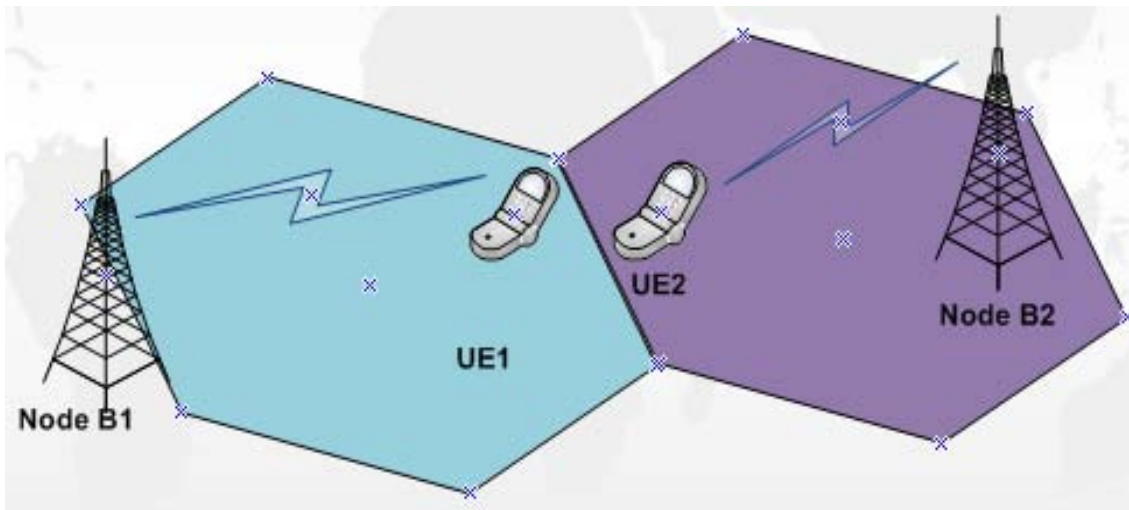


Figure 3.4: Hard handoff

Hard handoff takes place when the connection to the current cell is broken before a connection to a new cell is made, i.e. from one frame to the next one. Handoff is executed after the signal strength from neighbor's cell exceeding the signal strength from the current cell, Figure 3.4. There are different sub-types of hard handoff; inter-frequency, intra-frequency and inter-system. An inter-frequency hard handoff is made between two different frequencies within the same cell or adjacent cells. An intra-frequency hard handoff is performed in situations where the lur interface between two RNCs is not available for a soft handoff. A hard handoff is then performed from one cell belonging to one RNC to the next cell belonging to another RNC using the same frequency. Finally, an inter-system hard handoff is performed when it is required to change the radio access technology from UMTS to GSM [26].

However, in terms of PS services, there is one type of handoff defined for a UMTS network which is cell reselection. This is where the UE continuously monitors the signal quality from other cells as the user relocates.

On this, the UE is instructed to send a measurement report to the serving RNC when the quality of a neighboring cell exceeds a given threshold and thus the quality from the current cell is unsatisfactory.

Finally, when the cell re-selection has been completed, the UE initiates the routing area update procedure as described before [29].

#### IV. UMTS AND WLAN COMPARISON

Putting into consideration the complementary purposes rather than competitiveness, this chapter shows how the two technologies can be considered complementary. The two previous chapters described some basic characteristics of each of the technologies in terms of network architecture as well as mobility management.

Behind comparisons between UMTS and WLAN a summary in the form of a table (Table1) is shown below otherwise more details could be obtained in [32].

Table 1: 3G (UMTS) and WLAN comparison

Characteristics	3G-UMTS	WLAN
Services	Circuit- and packet-switched services	Packet-switched services
Data rates (Speed)	144 kbps satellite and rural areas min 120 km/h, max 500 km/h 384 kbps urban outdoor environments max 120 km/h 2 Mbps indoor and low range outdoor min 0 km/h, max 10 km/h	1 Mbps max 100 m (indoor) max 450 m (outdoor) 2 Mbps max 90 m (indoor) max 300 m (outdoor) 5.5 Mbps max 70 m (indoor) max 150 m (outdoor) 11 Mbps max 30 m (indoor) max 100 m (outdoor) 54 Mbps max 100 m (outdoor)
Coverage	Cellular, national/international coverage	Non-cellular, local coverage
Power control	Flexible power control	Max. effect of 100 mW required
Mobility	High, global (UMTS, UMTS-GSM)	Low, local (WLAN)
Deployment costs	Expensive	Cheap

Standardization bodies	Closed standardization body	Open standardization body
Technological origin	Telecommunication	Data communication
Air interface	WCDMA	HR-DS (High Rate Direct Sequence)
Channel Bandwidth	5 MHz	5 MHz
Chip rate	3.84 Mcps	11 Mcps
Frequency regulations	Regulated frequency spectrum	Unregulated frequency spectrum
Frequency band	WCDMA 1920-1980 MHz (up link) FDD 2110-2170 MHz (down link) 12 channels WCDMA 1900-1920 MHz TDD 2010-2025 MHz 7 channels New band 2500-2690 MHz	2.412-2472 GHz 13 channels
Speed	384 Kbps to 2 Mbps	11 Mbps to 54 Mbps

In a little bit of the above table1 description we find differences between the two network technologies include the range of supported services. The UMTS standard supports a variety of circuit- and packet-switched services whereas the WLAN specification only supports the corresponding packet-switched services.

In addition to the above, data rates is another significant difference where UMTS depending on the traveling speed environment supports data rates ranging from 144 kbps up to 2 Mbps. High mobility users, classed as users traveling over at 120 km/h and max 500 km/h in satellite and rural areas can expect data rates of 144 kbps. Full mobility user, such as at a speed less than 120 km/h and in urban outdoor environments, can expect 384kbps. Finally, low mobility users, those based indoor or at low range outdoor traveling at less than 10 km/h or stationary, in normal circumstances expect data rates of up to 2 Mbps as this could also be described in [33]. Opposite to the UMTS, WLAN depending on a specific environment supports data rates ranging from 1 Mbps up to 11 Mbps. However WLAN goes further to 54Mbps depending on IEEE 802.11 specification. More information about the how this varies can well be seen from the table 1 above.

Other differences such as coverage, power control, mobility, costs etc. are as well summarized clearly from Table 1.

It is thus expected that 3G will benefit over WLAN whose rate is very high, in terms of mobility and connectivity. On the other hand, WLAN benefits over 3G whose coverage area is big, in terms of throughput. Therefore, it is obvious that if the advantages of both technologies are combined, we will have a very powerful network covering the needs of the demanding users. WLAN is currently considered as a complementary service offering for mobile operators. Operator's WLAN solutions may vary but all of them combine the wide area benefits of second and third generation mobile systems, including unlimited roaming and mobility, with additional throughput and capacity in indoor hotspots through WLAN technologies. The complementary architecture for UMTS and WLAN technologies therefore, enables broadband mobile public access to the Internet as well as to corporate intranets with relatively small additional investment. However more detailed discussion can also be found in [34].

The network technology as we are emphasizing on UMTS and WLAN, specifically a connection is initially set to WLAN, which we defined as state 1, and then transitions between states 1 and 2 which is UMTS are governed by the two state Markov model shown in Figure 7.6.

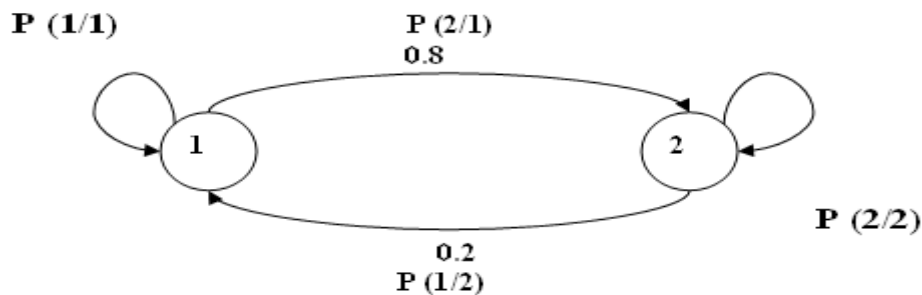


Figure 3.5: Two state Markov model

Transition probabilities are set to 0.8 from WLAN to UMTS and 0.2 from UMTS to WLAN which implies that the state probabilities for UMTS and WLAN

are 0.8 and 0.2, respectively, as given by the two Markov equations bellow;



$$P(1) = P(1/2) / \{P(1/2) + P(2/1)\} \quad (1)$$

$$P(2) = P(2/1) / \{P(1/2) + P(2/1)\} \quad (2)$$

*Idle State:* This is an unforced (red) state which pauses and after, executes its enter executives allowing the simulation to turn its attention to other entities and events in the model. This state is however interrupted by three different events; packet arrival, packet from queue and incoming registration request (location update) at any time. When an interrupt is received, the process transits to the next state.

*Arrival State:* This is a state that is invoked when an interrupt is received from the packet arrival event. A delay event is introduced when the packet is scheduled for sending from client to server or vice versa and this occurs while the packet is queued. Furthermore, the statistics for packet delays and packet counts are updated. As soon as the schedule times out the system returns to the idle state.

*Send State:* This state is entered when an interrupt is received from the packet at the end of the queue event. The packet is then sent on to the destination, and the system returns to the idle state.

*Loc State:* This state takes place when an interrupt is received from the incoming registration request event. Then from the function block the system executes the function location update during transition. In order to determine change of location and technology as well, the client-server or server-client delay values are slightly altered. As a result, the updated location update delay value occurs and also decides the type of network technology change that has occurred. WLAN network is set first by the initstate. The client probability estimate in WLAN was set to 0.2 whereas the probability of a client being in UMTS network amounts 0.8 as UMTS has a wider coverage. The description behind this scenario is that; when the outcome of the technology distribution function lies within 80%, i.e. less than 0.8, means that the network technology then has changed. Primarily the network technology being WLAN, the delay value increases by 31 ms because the network technology changes to UMTS. With estimations UMTS network is therefore adds an extra 31 ms delay (32 ms minus 1ms) compared to the WLAN which decreases the delay value by 31ms and whose distribution function falls within 20% thus changing from UMTS to WLAN. From the above description, when it occurs that the technology distribution function doesn't fall below the probability for network technology change value, this implies that vertical handoff did not take place, instead horizontal handoff occurred.

*Loc Arrival State:* During location update, this state is invoked on the packet arrival and the packet is however destroyed. In addition, the statistic for packet drop is

updated and thus the system returns to the loc state when it is done.

*Loc send State:* During location update, the loc send state is invoked if there are any packets in queue. The system takes the first packet out of the queue and sends it on to the destination. It then returns to the loc state. When the scheduled event location update delay from the location update function comes to an end, the event registration request complete takes place. The system consequently transits to the idle state. During the transition the system executes the function location update complete from the function block. The function location update complete involves updating the location update end time statistic.

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4. Manuscript to be submitted must include keywords, an abstract, a paper title, co-author(s) names and details (email address, name, phone number, and institution), figures and illustrations in vector format including appropriate captions, tables, including titles and footnotes, a conclusion, results, acknowledgments and references.
5. Authors should submit paper in a ZIP archive if any supplementary files are required along with the paper.
6. Proper permissions must be acquired for the use of any copyrighted material.
7. Manuscript submitted *must not have been submitted or published elsewhere* and all authors must be aware of the submission.

## Declaration of Conflicts of Interest

It is required for authors to declare all financial, institutional, and personal relationships with other individuals and organizations that could influence (bias) their research.

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Plagiarism is not acceptable in Global Journals submissions at all.

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Authors are solely responsible for all the plagiarism that is found. The author must not fabricate, falsify or plagiarize existing research data. The following, if copied, will be considered plagiarism:

- Words (language)
- Ideas
- Findings
- Writings
- Diagrams
- Graphs
- Illustrations
- Lectures



- Printed material
- Graphic representations
- Computer programs
- Electronic material
- Any other original work

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2. Drafting the paper and revising it critically regarding important academic content.
3. Final approval of the version of the paper to be published.

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The corresponding author should mention the name and complete details of all co-authors during submission and in manuscript. We support addition, rearrangement, manipulation, and deletions in authors list till the early view publication of the journal. We expect that corresponding author will notify all co-authors of submission. We follow COPE guidelines for changes in authorship.

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Unless specified in the notification, the Editorial Board's decision on publication of the paper is final and cannot be appealed before making the major change in the manuscript.

### Acknowledgments

Contributors to the research other than authors credited should be mentioned in Acknowledgments. The source of funding for the research can be included. Suppliers of resources may be mentioned along with their addresses.

### Declaration of funding sources

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## PREPARING YOUR MANUSCRIPT

Authors can submit papers and articles in an acceptable file format: MS Word (doc, docx), LaTeX (.tex, .zip or .rar including all of your files), Adobe PDF (.pdf), rich text format (.rtf), simple text document (.txt), Open Document Text (.odt), and Apple Pages (.pages). Our professional layout editors will format the entire paper according to our official guidelines. This is one of the highlights of publishing with Global Journals—authors should not be concerned about the formatting of their paper. Global Journals accepts articles and manuscripts in every major language, be it Spanish, Chinese, Japanese, Portuguese, Russian, French, German, Dutch, Italian, Greek, or any other national language, but the title, subtitle, and abstract should be in English. This will facilitate indexing and the pre-peer review process.

The following is the official style and template developed for publication of a research paper. Authors are not required to follow this style during the submission of the paper. It is just for reference purposes.



### ***Manuscript Style Instruction (Optional)***

- Microsoft Word Document Setting Instructions.
- Font type of all text should be Swis721 Lt BT.
- Page size: 8.27" x 11", left margin: 0.65, right margin: 0.65, bottom margin: 0.75.
- Paper title should be in one column of font size 24.
- Author name in font size of 11 in one column.
- Abstract: font size 9 with the word "Abstract" in bold italics.
- Main text: font size 10 with two justified columns.
- Two columns with equal column width of 3.38 and spacing of 0.2.
- First character must be three lines drop-capped.
- The paragraph before spacing of 1 pt and after of 0 pt.
- Line spacing of 1 pt.
- Large images must be in one column.
- The names of first main headings (Heading 1) must be in Roman font, capital letters, and font size of 10.
- The names of second main headings (Heading 2) must not include numbers and must be in italics with a font size of 10.

### ***Structure and Format of Manuscript***

The recommended size of an original research paper is under 15,000 words and review papers under 7,000 words. Research articles should be less than 10,000 words. Research papers are usually longer than review papers. Review papers are reports of significant research (typically less than 7,000 words, including tables, figures, and references)

A research paper must include:

- a) A title which should be relevant to the theme of the paper.
- b) A summary, known as an abstract (less than 150 words), containing the major results and conclusions.
- c) Up to 10 keywords that precisely identify the paper's subject, purpose, and focus.
- d) An introduction, giving fundamental background objectives.
- e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition, sources of information must be given, and numerical methods must be specified by reference.
- f) Results which should be presented concisely by well-designed tables and figures.
- g) Suitable statistical data should also be given.
- h) All data must have been gathered with attention to numerical detail in the planning stage.

Design has been recognized to be essential to experiments for a considerable time, and the editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned unrefereed.

- i) Discussion should cover implications and consequences and not just recapitulate the results; conclusions should also be summarized.
- j) There should be brief acknowledgments.
- k) There ought to be references in the conventional format. Global Journals recommends APA format.

Authors should carefully consider the preparation of papers to ensure that they communicate effectively. Papers are much more likely to be accepted if they are carefully designed and laid out, contain few or no errors, are summarizing, and follow instructions. They will also be published with much fewer delays than those that require much technical and editorial correction.

The Editorial Board reserves the right to make literary corrections and suggestions to improve brevity.



## FORMAT STRUCTURE

***It is necessary that authors take care in submitting a manuscript that is written in simple language and adheres to published guidelines.***

All manuscripts submitted to Global Journals should include:

### **Title**

The title page must carry an informative title that reflects the content, a running title (less than 45 characters together with spaces), names of the authors and co-authors, and the place(s) where the work was carried out.

### **Author details**

The full postal address of any related author(s) must be specified.

### **Abstract**

The abstract is the foundation of the research paper. It should be clear and concise and must contain the objective of the paper and inferences drawn. It is advised to not include big mathematical equations or complicated jargon.

Many researchers searching for information online will use search engines such as Google, Yahoo or others. By optimizing your paper for search engines, you will amplify the chance of someone finding it. In turn, this will make it more likely to be viewed and cited in further works. Global Journals has compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

### **Keywords**

A major lynchpin of research work for the writing of research papers is the keyword search, which one will employ to find both library and internet resources. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining, and indexing.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy: planning of a list of possible keywords and phrases to try.

Choice of the main keywords is the first tool of writing a research paper. Research paper writing is an art. Keyword search should be as strategic as possible.

One should start brainstorming lists of potential keywords before even beginning searching. Think about the most important concepts related to research work. Ask, "What words would a source have to include to be truly valuable in a research paper?" Then consider synonyms for the important words.

It may take the discovery of only one important paper to steer in the right keyword direction because, in most databases, the keywords under which a research paper is abstracted are listed with the paper.

### **Numerical Methods**

Numerical methods used should be transparent and, where appropriate, supported by references.

### **Abbreviations**

Authors must list all the abbreviations used in the paper at the end of the paper or in a separate table before using them.

### **Formulas and equations**

Authors are advised to submit any mathematical equation using either MathJax, KaTeX, or LaTeX, or in a very high-quality image.

### **Tables, Figures, and Figure Legends**

Tables: Tables should be cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g., Table 4, a self-explanatory caption, and be on a separate sheet. Authors must submit tables in an editable format and not as images. References to these tables (if any) must be mentioned accurately.





## Figures

Figures are supposed to be submitted as separate files. Always include a citation in the text for each figure using Arabic numbers, e.g., Fig. 4. Artwork must be submitted online in vector electronic form or by emailing it.

## PREPARATION OF ELETRONIC FIGURES FOR PUBLICATION

Although low-quality images are sufficient for review purposes, print publication requires high-quality images to prevent the final product being blurred or fuzzy. Submit (possibly by e-mail) EPS (line art) or TIFF (halftone/ photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Avoid using pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings). Please give the data for figures in black and white or submit a Color Work Agreement form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution at final image size ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs): >350 dpi; figures containing both halftone and line images: >650 dpi.

Color charges: Authors are advised to pay the full cost for the reproduction of their color artwork. Hence, please note that if there is color artwork in your manuscript when it is accepted for publication, we would require you to complete and return a Color Work Agreement form before your paper can be published. Also, you can email your editor to remove the color fee after acceptance of the paper.

## TIPS FOR WRITING A GOOD QUALITY COMPUTER SCIENCE RESEARCH PAPER

Techniques for writing a good quality computer science research paper:

**1. Choosing the topic:** In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

**2. Think like evaluators:** If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

**3. Ask your guides:** If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

**4. Use of computer is recommended:** As you are doing research in the field of computer science then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

**5. Use the internet for help:** An excellent start for your paper is using Google. It is a wondrous search engine, where you can have your doubts resolved. You may also read some answers for the frequent question of how to write your research paper or find a model research paper. You can download books from the internet. If you have all the required books, place importance on reading, selecting, and analyzing the specified information. Then sketch out your research paper. Use big pictures: You may use encyclopedias like Wikipedia to get pictures with the best resolution. At Global Journals, you should strictly follow here.



**6. Bookmarks are useful:** When you read any book or magazine, you generally use bookmarks, right? It is a good habit which helps to not lose your continuity. You should always use bookmarks while searching on the internet also, which will make your search easier.

**7. Revise what you wrote:** When you write anything, always read it, summarize it, and then finalize it.

**8. Make every effort:** Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

**9. Produce good diagrams of your own:** Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

**10. Use proper verb tense:** Use proper verb tenses in your paper. Use past tense to present those events that have happened. Use present tense to indicate events that are going on. Use future tense to indicate events that will happen in the future. Use of wrong tenses will confuse the evaluator. Avoid sentences that are incomplete.

**11. Pick a good study spot:** Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

**12. Know what you know:** Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

**13. Use good grammar:** Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

**14. Arrangement of information:** Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

**15. Never start at the last minute:** Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

**16. Multitasking in research is not good:** Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

**17. Never copy others' work:** Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

**18. Go to seminars:** Attend seminars if the topic is relevant to your research area. Utilize all your resources.

**19. Refresh your mind after intervals:** Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.



**20. Think technically:** Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.

**21. Adding unnecessary information:** Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.

**22. Report concluded results:** Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.

**23. Upon conclusion:** Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium through which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

## INFORMAL GUIDELINES OF RESEARCH PAPER WRITING

### **Key points to remember:**

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

### **Final points:**

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

*The introduction:* This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

### **The discussion section:**

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

### **General style:**

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

**To make a paper clear:** Adhere to recommended page limits.



### *Mistakes to avoid:*

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.
- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

### **Title page:**

Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

**Abstract:** This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

*Reason for writing the article—theory, overall issue, purpose.*

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

### **Approach:**

- Single section and succinct.
- An outline of the job done is always written in past tense.
- Concentrate on shortening results—limit background information to a verdict or two.
- Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

### **Introduction:**

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.



*The following approach can create a valuable beginning:*

- Explain the value (significance) of the study.
- Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- Briefly explain the study's tentative purpose and how it meets the declared objectives.

#### **Approach:**

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

#### **Procedures (methods and materials):**

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

#### **Materials:**

*Materials may be reported in part of a section or else they may be recognized along with your measures.*

#### **Methods:**

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

#### **Approach:**

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

#### **What to keep away from:**

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- Leave out information that is immaterial to a third party.





**Results:**

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

**Content:**

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

**What to stay away from:**

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

**Approach:**

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

**Figures and tables:**

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

**Discussion:**

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."



Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

**Approach:**

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

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Administration Rules to Be Strictly Followed before Submitting Your Research Paper to Global Journals Inc.

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*Written material:* You may discuss this with your guides and key sources. Do not copy anyone else's paper, even if this is only imitation, otherwise it will be rejected on the grounds of plagiarism, which is illegal. Various methods to avoid plagiarism are strictly applied by us to every paper, and, if found guilty, you may be blacklisted, which could affect your career adversely. To guard yourself and others from possible illegal use, please do not permit anyone to use or even read your paper and file.



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BY GLOBAL JOURNALS INC. (US)

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Topics	Grades		
	A-B	C-D	E-F
<i>Abstract</i>	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form  Above 200 words	No specific data with ambiguous information  Above 250 words
<i>Introduction</i>	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
<i>Methods and Procedures</i>	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
<i>Result</i>	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
<i>Discussion</i>	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
<i>References</i>	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring



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