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An Empirical Approach to Mobile Learning on Mobile Ad Hoc Networks (MANETs)

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Abstract: Mobile Ad hoc Networks (MANETs) are made up of mobile nodes that are interconnected wirelessly, while topology changes as mobile nodes join and leave the network. MANETs do not depend on fixed infrastructure. Due to their dynamism and low cost (no infrastructure is needed), MANETs have been proposed as a mechanism suitable for carrying out mobile learning (m-Leaning) in developing countries. However, systematic literature review indicates that the existing MANETs-based m-Learning models are disadvantaged because they fail to identify possible routing protocols able to support such models. As a result, it becomes very difficult to implement the existing MANET-based m-Learning models. This paper characterizes MANETs-based m-Learning proposed by [1]. Thereafter, it uses area, nodes, and data packets information as basic scalar parameters on Zone Routing Protocol (ZRP) simulated on NS-2 and ZRP code supplemented with positional and directional information of nodes in the Intrazonal Routing Protocol (IARP) on OMNET++. According to simulation results, a directional-positional enhanced ZRP outperforms regular ZRP on packet delivery ratio, delay and overall data packet throughput. Results from the simulation suggests that a supplemented ZRP is a feasible routing protocol for supporting m-Learning in a typical university campus based on the identified basic scalar parameters and characterization of [1].

Key Terms: Mobile Ad-Hoc Networks (MANET), Zone Routing Protocol (ZRP), Intrazonal Routing Protocol (IARP)

1. Introduction

Mobile Ad hoc Networks (MANETs) are composed of self-configuring mobile nodes linked through wireless connections [2]. Rai et al. [2] note that MANETs' nodes that are adjacent to each other may transmit information between them, while depending on immediate nodes to pass data packets and network topological information to other nodes in the network. A mobile node may serve either as a sender, receiver or a router.

Mobile Ad-hoc Networks (MANETs) are described by their ability to multi-hop, self-configure, and their fluidity as nodes join and leave the network. MANETs are made up of cluster(s) of mobile devices whose terminals are connected wirelessly. Mobile terminals serve both as the receiver and the transmitter of information—router and host. MANETs require no infrastructure while at the same time being very dynamic [3].

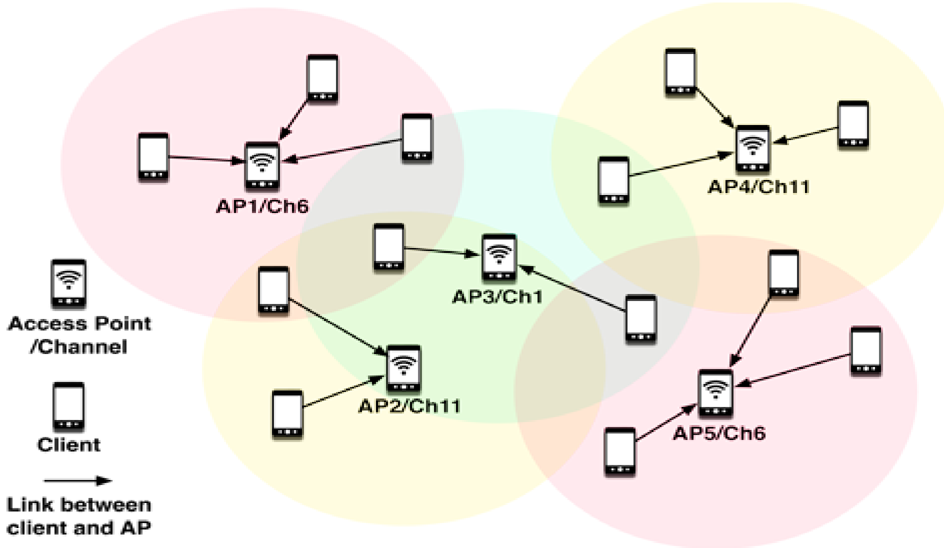

Figure 1: Example of a MANET. Adopted from [4]

Proposal [1] suggests usage of a Telecentre furnished with a server that is linked to the Internet through cables and wireless connection. The proposed model is meant to be used in Zambia. However, a keen examination of Figure 1 reveals a key shortcoming. That is, without technical specifications of the model, it makes it hard for implementation. For example, what possible routing protocols applicable in the model? Absence of possible routing protocols in such a diagram makes it very hard to assess its viability.

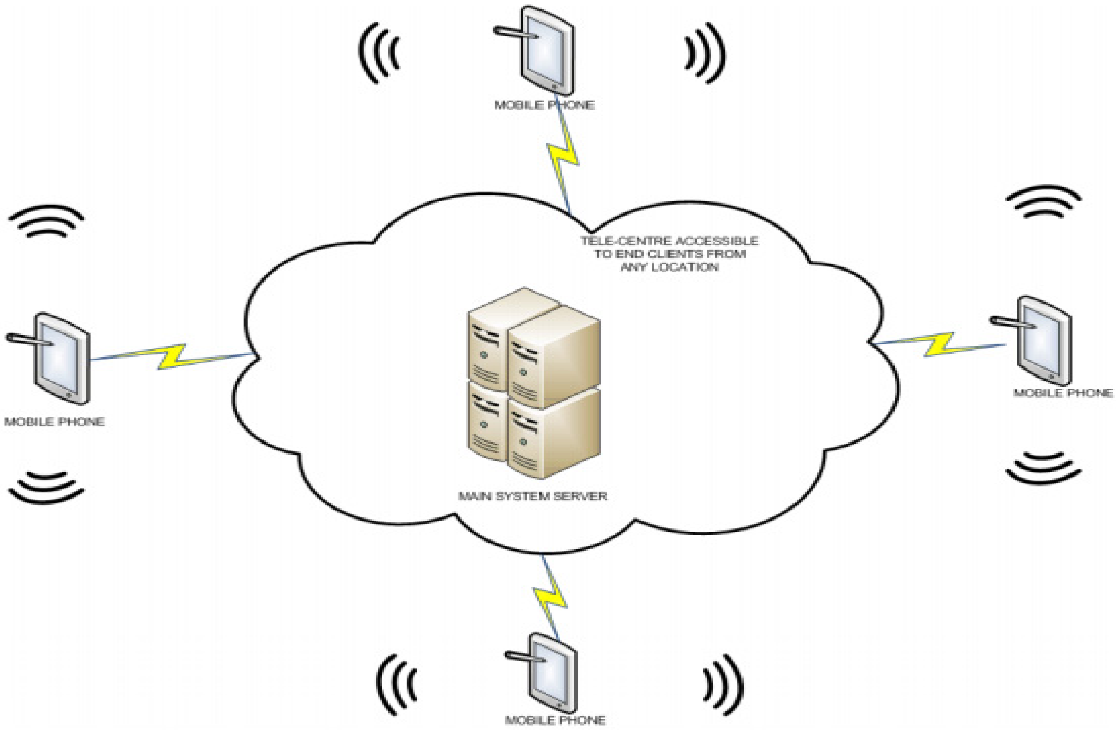

Figure 2: Network diagram. Adopted from [1]

Short-lived responses do not call for the availability of permanent infrastructure, hence making MANETs applicable solutions in emergency and combat zones [5]. Lately, however, MANETs have found more uses as wireless network advances. With time, research on MANETs has expanded to encompass other areas such as education [6], [7], and business. Particularly in education, MANETs have proved useful due to their self-organizing nature. Ubiquity in education needs systems that are as dynamic as MANETs.

Mobile communication terminals can enable learners from underprivileged learning institutions or areas to access voice, text and other multimedia from the better resourced neighboring learning institutions. Smartphones and other smart PDAs have the ability to form MANETs for knowledge sharing and as a result, the quality of learning can improve. Because MANETs are not limited by either time or space/place in the access and sharing of knowledge, the learning participants may assume learning at any location at any time. Within a MANET, every mobile device is capable of moving around in the directions of choice, thus changing the nodes/devices to which they are connected. If a certain mobile device receives routing information that does not belong it, it should forward it to another node. Such a process is repeated until the routing information reaches the appropriate node or device [8].

MANETs do not rely on pre-existing infrastructure. Establishment of MANETs systems can be carried out based on the needs of a situation. Since infrastructure such as the Base Stations are not required to set up MANETs, the cost is low. Existing literature on MANETs and m-Learning reveal various suggested models that are not supported by either empirical data or underlying routing protocols. With an ever-increasing number of potential learners in the developing countries, MANETs based m-Learning can be implemented at low costs as a complement to the inadequate learning facilities. For instance, many universities in Sub-Saharan Africa are inadequately equipped to offer quality education to all learners seeking an education.

Due to their topological dynamism, however, MANETs experience several challenges. For example, because MANETs are wireless, the energy required to transmit and route packets can be higher than in wired networks. Constant updates of routing information are also needed although no transmission has taken place. Collision of routing updates is also common in highly connected MANETs.

This study outlines and discusses similar works on empirical MANETs, objectives of study, the proposed empirical model and the presentation, analysis and discussions of results.

2. Objectives

The main purpose of this study was to establish, through characterization and simulation, an appropriate model that describes how learning can be enhanced through MANETs in a typical university campus in developing countries. Specific objectives of this study included the following:

1. To establish an appropriate formula/guide for creating MANET-based m-Learning capable of distributing learning resources in a typical university campus
2. To empirically (through simulation) identify a possible routing protocol capable to support a MANET-based m-Learning in a typical university campus

2.1 Related Work

In [22] the facets of transactional distance theory to propose a pedagogy-based m-Learning model is proposed. The proposed model categorizes mobile learning into four types. According to [22], it offers a comprehensive analysis of the literature from which m-Learning types are identifies. Based on the model proposed in [22] the four types of mobile learning include; high transactional distance socialized m-learning, high transactional distance individualized m-learning, low transactional distance socialized m-learning, and low transactional distance individualized m-learning. For these types of m-Learning to occur, mobile devices must be present - acting as enablers. The main purpose of the proposed model is to help instructional designers of open and distance learning to deal with a possible psychological gap between the learning participants. That is, mainly learners and the learning facilitators. Included in the model is the suggestion that social aspect of individual learners ought to also be considered while creating mobile learning processes.

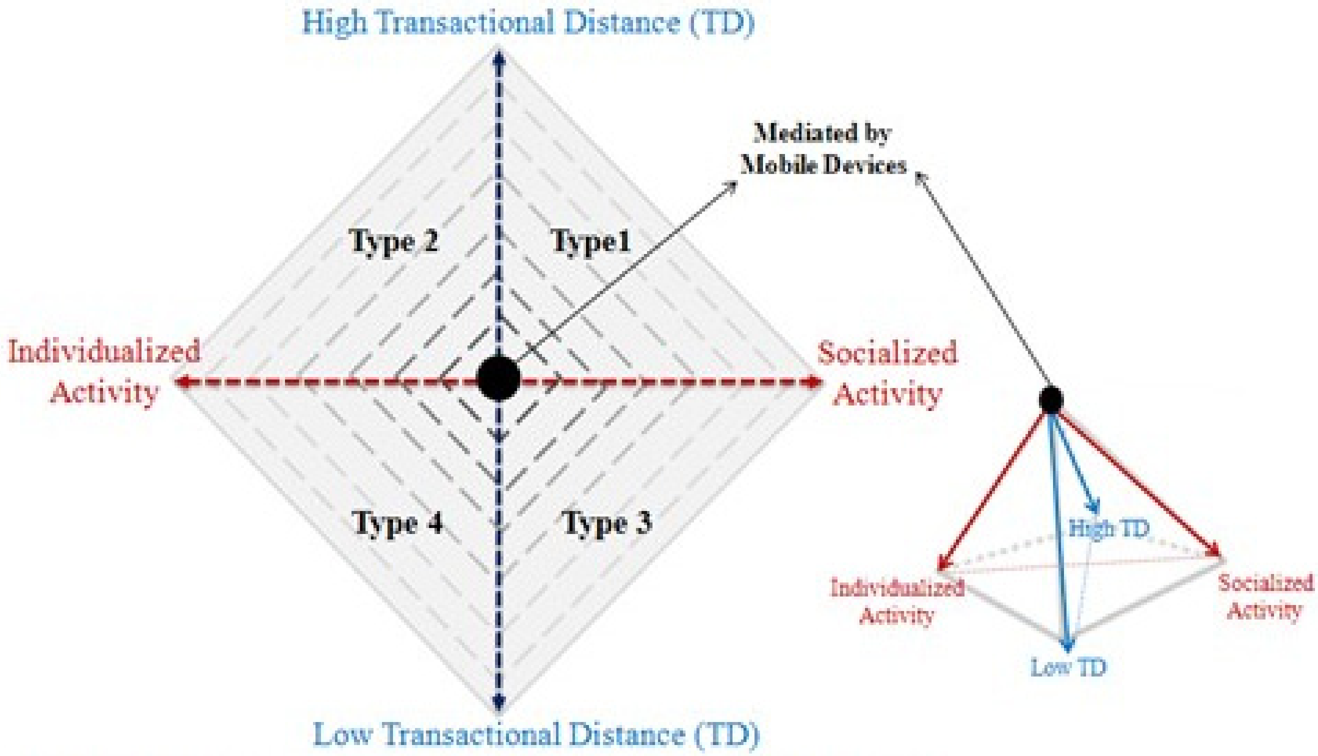

Figure 3: Four Types of mobile learning: Adopted from [22]

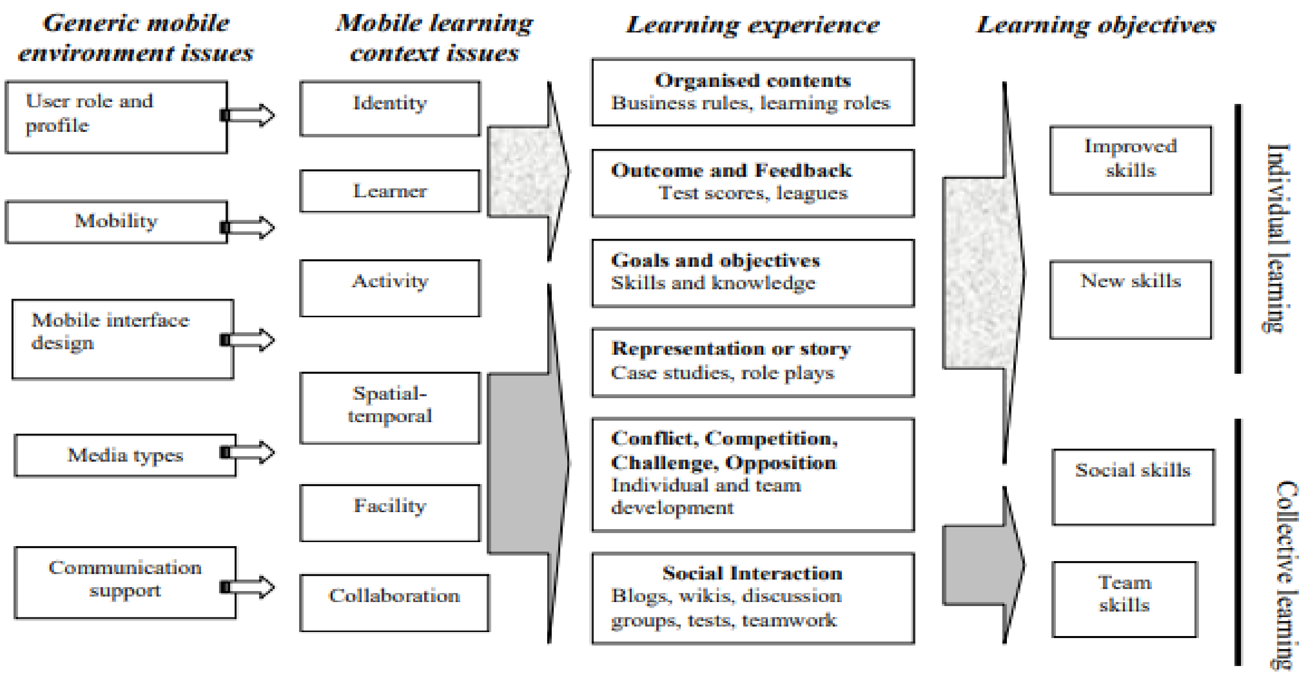

Figure 4: A model for M-learning design requirements. Adopted from [23]

According to [23] mobile learning must feature and consider four viewpoints. Constructed in their proposed m-Learning model is the idea that a mobile learning environment must factor in four ideas. That is, generic mobile environment issues - mobile interface design, learning contexts, learning experiences, and learning objectives. Within [23] mobile learning model, the interaction aspect is also included. The interaction aspect is meant to consider various needs in both grouped or individualized mobile learning environments. A vital trait of this model is the fact that it very detailed. Every factor or category is broken further into subgroups, thus providing vital information. After proposing this model, [23] used its components to scrutinize four mobile learning projects. By examining implemented mobile learning projects using their model, they were able to show how to deploy it in mobile learning environments for evaluations.

MANETs are viewed as future critical component of the Internet of Things (IoT). Once objects in an IoT are without the infrastructure networks, MANETs may be vital in ensuring connectivity. MANETs enables creation of subnets, hence IoT objects may hop from one network to another [22]. Although IoT's potential is yet to be fully exploited, MANETs are seen as technological addendum that is likely to make it possible to exploit its potential. MANETs based IoT may contribute in the improvement of society because it can enable creation of smart objects and create a more interconnected environment. Some of the areas that will require smart MANETs include transportation, military, healthcare, farming, education and emergency response situations.

Currently, technology continues to infiltrate and transform education. This trend is likely to continue as technology advances and becomes more pervasive in our daily lives. With the widespread of the Internet and the increase in the use of smart devices - mostly miniaturized and optimized in performance, experts and researchers seek ways of establishing affordable and reliable networks appropriate for mobile learning (m-Learning) [23]. Mobile Ad Hoc Networks (MANETs) in particular have been proposed in the creation of virtual classrooms to enable dissemination and sharing of learning resources [1]. However, these m-Learning models do not include empirical data to enable implementation.

3. Research Methodology

Selection of the routing protocol to be simulated and enhanced was determined through purposive sampling [9] and systematic comparative review of literature [21]. Determining likely supplementary behavior of the MANETs routing protocols, eight routing protocols from the routing categories highlighted in [11], [12] and [13] were selected for review. From each of the categories, two routing protocols were selected randomly. Consequently, this study selected Optimized Link State Routing (OLSR) and Destination-Sequenced Distance Vector (DSDV) to represent flat-proactive category, while Ad hoc On-Demand Distance Vector (AODV) and Dynamic Source Routing (DSR) were selected to represent flat-reactive category. However, if a routing protocol appears in two of the three selected categorizations [11], [12] and [13], were selected automatically. The other routing protocol was selected randomly.

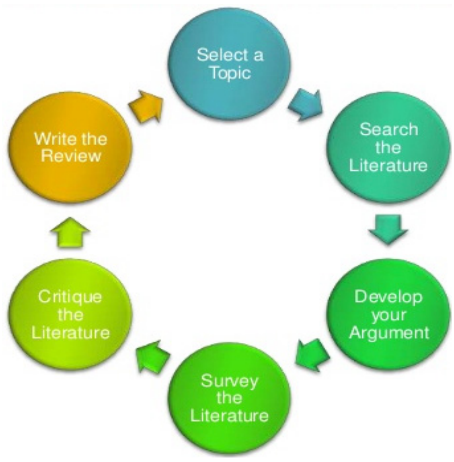

Figure 5: Literature Review Process. Adopted from [21]

To achieve the objectives of this study, purposive sampling of articles to be reviewed was applied [9], and systematic review process [21] was used with literature criticism and study argument development. The purposive sampling was meant to single out the most dynamic routing protocol to be deployed in the proposed model. Consequently, comparative review identifies Zone Routing Protocol (ZRP) as a viable MANET routing protocol because it combines reactive and proactive routing features. Afterwards, ZRP is simulated on NS2 while a position-location enhanced ZRP code was run on OMNET++. Simulation results were based on three basic initial scalar parameters—area, nodes, data packets. The model to be enhanced was selected based on the basis that it is proposed for a developing country.

4. Technology Description

4.1 Zone Routing Protocol (ZRP)

Zone Routing Protocol (ZRP) was suggested by Haas and Pearlman [15], [16]. In a ZRP, each node is assigned to a routing zone within the ad hoc network. Routing zones in ZRP are subnetworks whose radius is determined by the number of hops. ZRP takes the advantages availed by both the proactive and reactive routing protocols. Nodes in a local zone deploy proactive routing protocol to speed up inter nodal transmission. Communication between zones is facilitated by a reactive routing protocol to combat possible network overheads [18]. Routing zones in a ZRP are determined by the hops distance between one node and another. For instance, if node ***N*** uses a proactive routing protocol to transmit packets to nodes that ***h*** hops from it, then the radius of the zone is ***h*** hops.

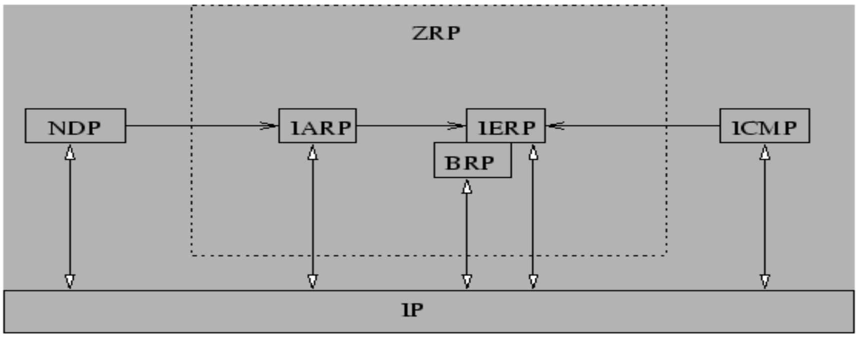

Figure 6: ZRP Components [15]

ZRP depends on the Intrazonal Routing Protocol (IARP) for zonal communication and routing table updates. Beyond a zone's radius, ZRP calls upon Interzone Routing Protocol (IERP) for the transmission of packets. Regulation of routing information between nodes within a zone is carried out by IARP, while IERP border casts routing requests to the peripheral nodes.

While implementing the IARP, various proactive protocols may be used [2]. For example, IARP may be implemented based on a modified version of Distance Vector algorithm. The Distance Vector algorithm restricts packets transmission to within a zone routing radius. A node can extract new route information either from a received IARP packet or from an interrupt created by its Neighbor Discovery Maintenance (NDM) process. The IARP terminal nodes may transmit neighboring nodes the shortest route. Nonetheless, this takes place only in special instances when host nodes know the topological information of the neighbor. Upon transmitting the shortest route information receiving node then records the new route information in its Intrazone Routing Table. Additionally, all changes in the route information are also broadcast through the AIARP.

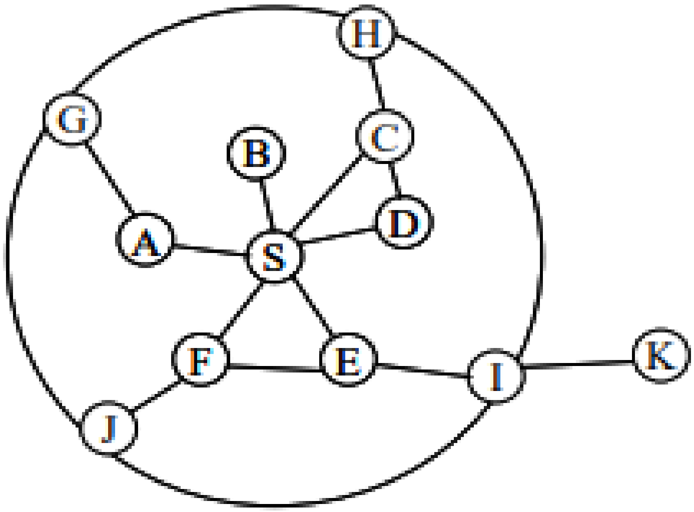

Figure 7: Example routing zone with ρ=2. Adopted from [15]

IARP is dependent on the services of a separate protocol referred as the Neighbor Discovery/Maintenance Protocol to avail the current information about a host's neighbors. In its minimum, the information relayed should include the IP addresses of all the neighbors. Moreover, the IARP can be comfortably configured to sustain complementary neighbor information. Such information may include the cost of the link. The following is the original IARP algorithm.

```
D.1
    Event:   An IARP packet is received containing route
             information to a destination D. The hop count
             associated with the received route is LESS THAN
             the routing zone radius.

    Action:  The received route is recorded in the Intrazone
             Routing Table. If the received route is shorter
             than the previous shortest route to D, then a new
             IARP packet containing route information to D
             through X is broadcasted.

D.2
    Event:   An IARP packet is received containing route
             information to a destination D. The hop count is
             EQUAL TO the routing zone radius.

    Action:  The received route is recorded in the Intrazone
             Routing Table.

D.3
    Event:   An IARP packet is received containing route
             information to a destination D. The hop count is
             equal to INF.

    Action:  The route to D is removed from the Intrazone
             Routing Table.
                1) If the Intrazone Routing Table still
                contains a route to D and the length of the
                shortest route has increased due to the route
                removal, then the an IARP packet containing the
                shortest route to D through X is broadcasted.
                2) If the Intrazone Routing Table contains no
                more routes to D, then an IARP packet containing
                a route to D through X with hop count of INF is
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                   broadcast.  A "Host Lost" interrupt is
                   generated to alert the IERP that D has moved
                   beyond the routing zone.

D.4
    Event:   A "Neighbor Found" interrupt is received,
             indicating the discovery of a neighbor host N.

    Action:  For each destination in X's Intrazone Routing
             Table, an IARP packet is sent to N containing the
             best route to that destination. An IARP packet is
             then broadcasted containing the 1 hop route to N
             through X.
D.5
    Event:   A "Neighbor Lost" interrupt is received, indicating
             that host N is no longer a neighbor of X

    Action:  The one hop route to N is removed from the
             Intrazone Routing Table.
                1) If the Intrazone Routing Table still
                contains a route to N and the length of the
                shortest route has increased due to the route
                removal, then the an IARP packet containing the
                shortest route to N through X is broadcasted.
                2) If the Intrazone Routing Table contains no
                more routes to N, then an IARP packet containing
                a route to D through X with hop count of INF is
                broadcast. A "Host Lost" interrupt is generated
                to alert the IERP that D has moved beyond the
                routing zone.
```

5. The Proposed ZRP Enhanced Routing Protocol

Since in ZRP, proactive routing zones severely overlap, query control traffic may increase [24]. Besides, "since the actual implementation of IARP and IERP is not defined, the performance can be further improved by adapting other routing protocols as ZRP components" [24]. Furthermore [25] notes that one of the shortcomings of ZRP is lack of use of location information in route discovery query. Location aware routing helps in reducing some these shortcomings to some degree [26]. Through the use of a Global Positioning System (GPS), it is possible to minimize the query traffic [27].

In this study, a position algorithm that replaces the hop-count based radius is proposed. Because the implementation of IARP is not defined - it is open to be modified based on scenario needs, we propose that instead of defining zone radius with the hops counts to the peripheral nodes, an expected zone and a request zone is determined based on the transmission range of a node.

While the IARP can be implemented through various proactive protocols, this study considers the algorithm of the Distance Vector as presented in [28] and [29]. The algorithm is modified to fit the location information of a node, thus eliminating the need for zone radius.

The modified algorithm allows reception of new route information by a source node as transmitted within the request zone. In case a node is not found within the request zone, the invocation of Neighbor Discovery/Maintenance occurs. Communications between the source node and the destination node takes place if the two nodes are within the request zone. The location information exchanged includes the distance between the nodes and the Angle of Arrival (AoA). The received new location information can then be stored by the source node in its Intrazone Routing Table. Updating of location information is carried out in the IARP through the Neighbor Discovery/Maintenance Protocol.

D.1

Event: An IARP packet is received containing location information to a destination D. The distance and the Angle of Arrival (AoA) associated with the received route lies within the request zone.

Action: The received location information is recorded in the Intrazone Routing Table. If the received distance and the Angle of Arrival (AoA) have changed then the new location information is recorded.

D.2

Event: An IARP packet is not received containing location information to a destination D. The location information is not within the request zone

Action: The route request is retransmitted to the nodes whose location in the request zone is largest in regressing sequence.

D.3

Event: The appropriate node is identified and an IARP packet is received containing location information to a destination D.

Action: The location information to D is removed from the Intrazone

D.4

Event: A "Neighbor Found" interrupt is received, indicating the discovery of a neighbor host N.

Action: For each destination in X's Intrazone Routing Table, an IARP packet is sent to N containing the Location information to that destination. An IARP packet Is then broadcasted containing the location information N through X.

D.5

Event: A "Neighbor Lost" interrupt is received, indicating that host N is no longer a neighbor of X

Action: The location information to N is removed from the intrazone table

4.2 NS2 and OMNET++ Simulators

Network Simulator (Version 2), commonly branded as NS2, is discrete event-driven simulation environment. With time, it has entrenched itself as a valuable tool for "studying the dynamic nature of communication networks" [19, p.1]. Simulation of wireless network functions and protocols such routing algorithms can be done using NS2. Generally, NS2 offer researchers an opportunity to specify such network protocols and simulating their corresponding behaviors. Because of its flexibility and modular nature, NS2 is continuously accepted as dependable research tool in the networking research community since its creation in 1989.

NS2 offer users with an executable command "ns" which takes one input argument. The input argument is the name of a Tcl simulation scripting file. Generally, a simulation trace file is created and for the purposes of plotting graphs and/or producing animation. NS2 comprises of two crucial programming languages. These are: C++ and Object-oriented Tool Command Language (OTcl). C++ is applied in defining the internal mechanisms, for example, the backend of the simulation, while the OTcl creates simulation by collecting and configuring the objects and scheduling discrete events—frontend. The C++ and the OTcl are linked with TclCL. Variables (normally mapped to C++ objects) in the OTcl domains are often called handles.

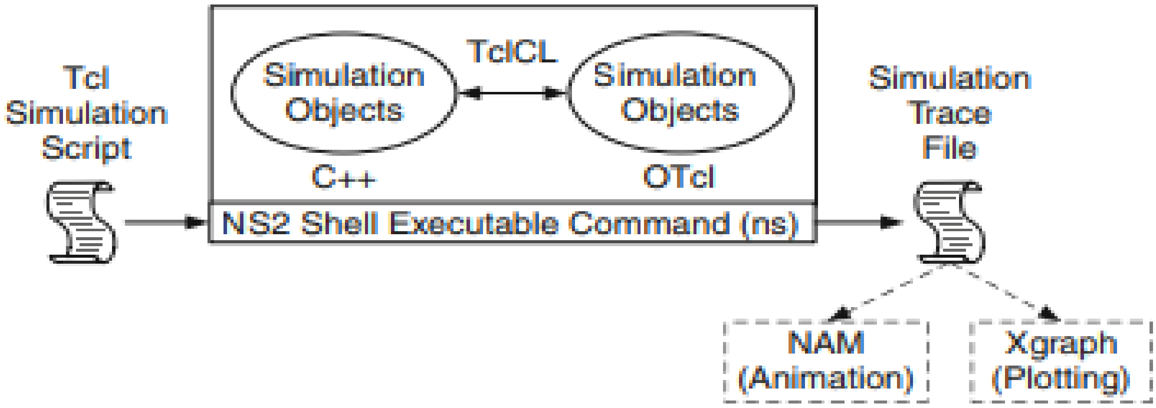

Figure 8: Basic architecture of NS2. Adopted from [19]

OMNeT++ is an "extensible, modular, component-based C++ simulation library and framework, primarily for building network simulators" [20, p.1]. It can be used to to simulate wired networks, wireless networks, on-chip networks, and queueing networks. Morever, domain-specific functionality such as support for sensor networks, wireless ad-hoc networks, Internet protocols, performance modeling, photonic networks is provided by model frameworks, initiated as autonomous modules. OMNeT++ provides an Eclipse-based IDE and a graphical runtime environment. The core constituents of OMNeT++ are the simulation kernel library (C++), the NED topology description language and an interactive simulation runtime GUI (Qtenv) .

6. Results

By applying initial basic scalar parameters to simulate ZRP and its positional-directional enhanced version, this paper sought to determine the following:

-Received Data Packets
-Average Delay
-Packets drop rate
-Data Packet throughput

Table 1: initial basic scalar parameters

Parameter	Value
Number of nodes	50
Area	300m*300m
Packet Size	512 bytes
Simulation time	200s
Number of Simulations	20

From the simulation results, location-position enhanced ZRP outperforms traditional ZRP, however with a small but steady margin. Although the differences form the curves may not seem large, its cumulative effects can be enormous in large networks. As the number of nodes increases, the seemingly subtle difference adds to augment efficiency. Results analysis and the overall cumulative principle hold true in other basic scalar parameters as shown in Figures 9, 10 and 11.

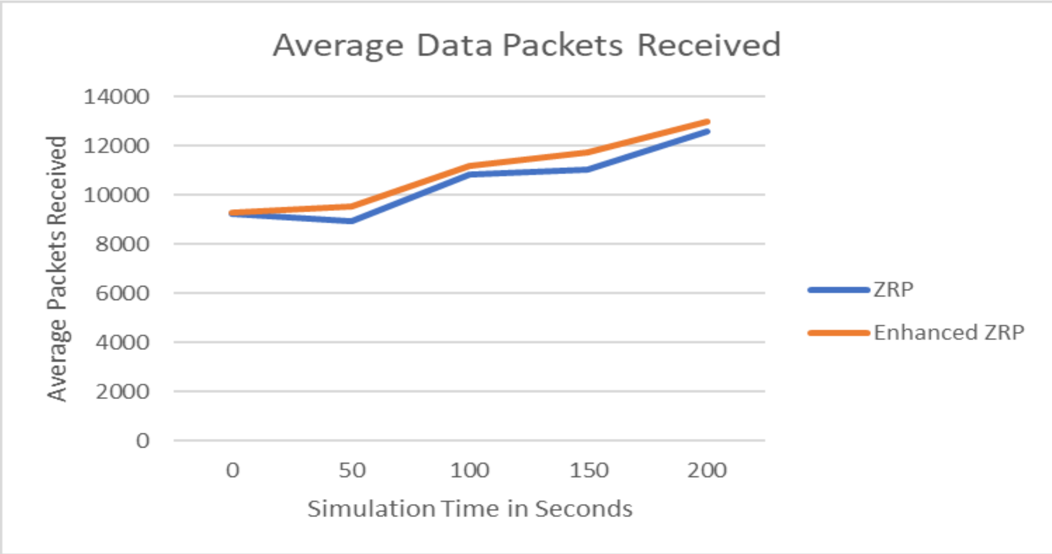

Figure 9: Average Packet Received

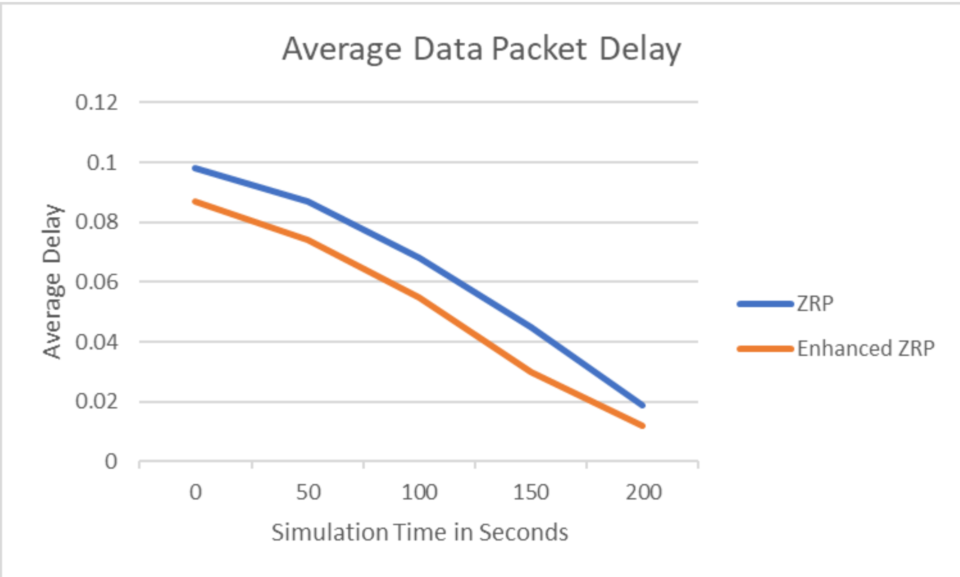

Figure 10: Average Delay

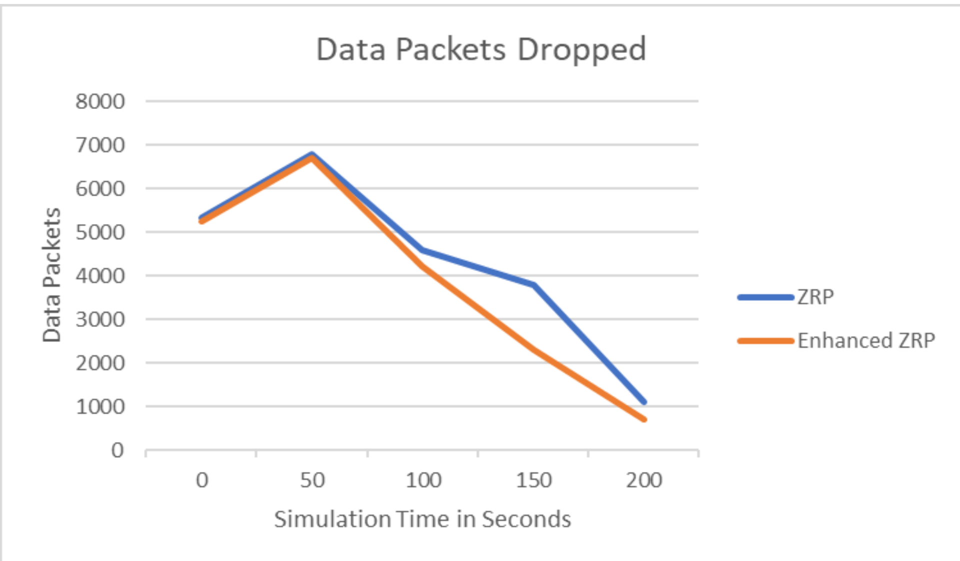

Figure 11: Data Packets

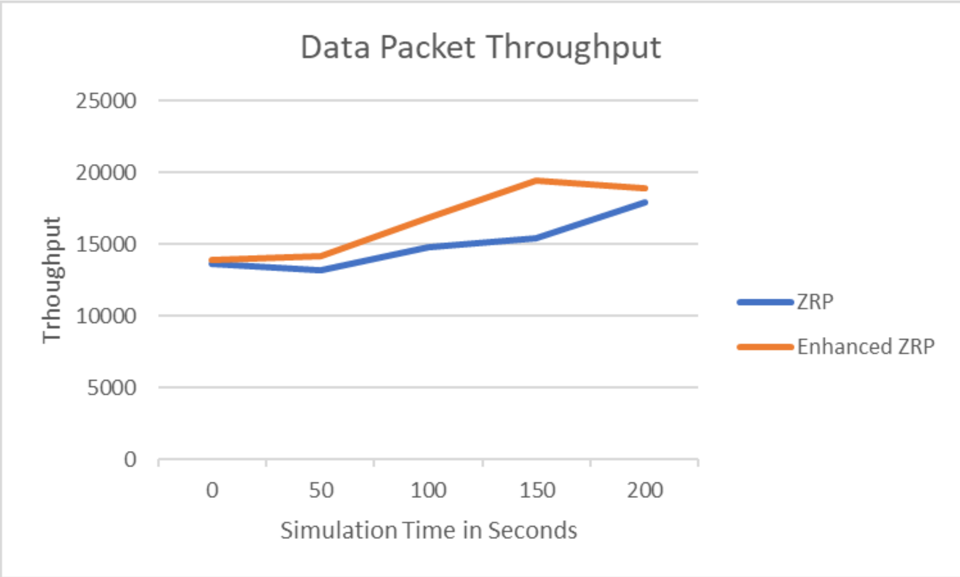

Figure 12: Data Packets Throughput

Overall, the results suggests that an ehanced ZRP is probable for supporting a typical learning in a campus. Therefore, it possible to use enhanced ZRP on m-Learning [1]. By combing the two, we proposed that the new improved model assume the characteristics of Figure 13.

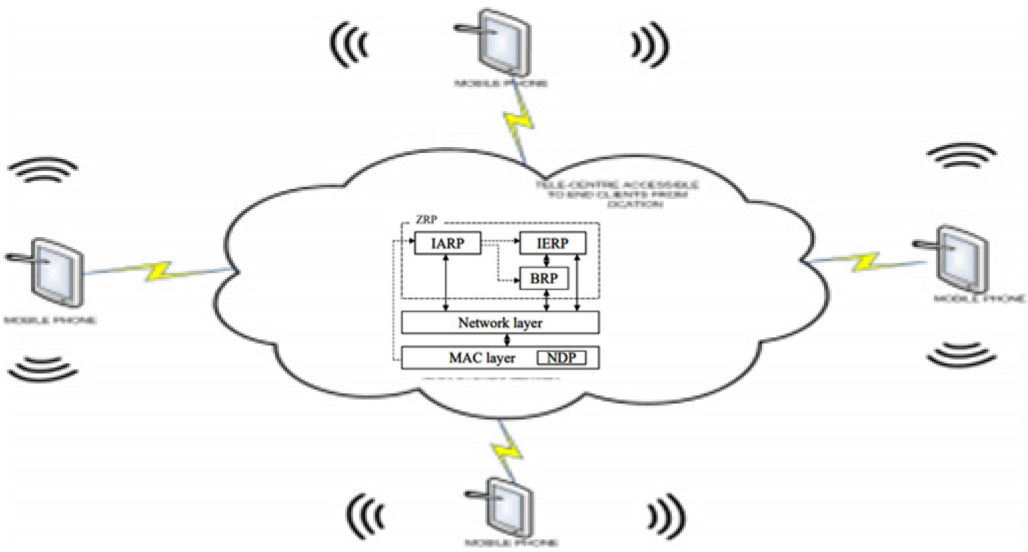

Figure 13: Revised MANET-based m-Learning Model

7. Benefits

In the 21st Century, access to quality and affordable education is very vital. Several organizations and governments regard the access to quality education to every human being as important in poverty reduction and the overall improvement of personal economic status in particular and the society in general. Any effort to provide quality education cheaply would surely, be welcome.

One of the ways of providing quality education to the people is by tapping the ability of the available technologies. Among the available technologies that can be tapped to provide such avenues to access quality education is the MANETs. MANETs can be used in the creation of virtual classrooms especially in the poor areas such as the slums. But this is only achievable if the available m-Learning models include empirical and technical details to the characterizations of their proposals. Through simulation, this study empirically demonstrates possible formulation of MANETs learning models that are implementable due to inclusion of technical details such as inclusion of possible routing protocols. As this paper demonstrates, the m-Learning model [1] can be more implementable provided that technical details are included.

8. Conclusion and Future Work

While there are studies examining the usage of MANETs for affordable and quality of education in developing countries, the essential technical details such as possible routing protocols are lacking. The MANETs learning models proposed thus far are difficult to implement because they do not specify technical exactitudes paramount to network engineers and administrators. For instance, all reviewed proposed MANETs learning models do not highlight the possible technical components of critical network layers such as application and network.

In an attempt to improve the existing MANETs models, this study, through systematic literature review and simulation, includes an enhanced ZRP to model [1] as possible technical inclusion at OSI network layer. Consequently, simulation indicates that inclusion of position-location topological data to conventional ZRP algorithm boosts the general outputs of four selected scalar parameters evaluated on simulated time.

However, this study used time (fixed at 400 seconds) as variable metric for simulation. Consequently, it is suggested that further simulations be conducted on composite variables such as the number of nodes. Using number of nodes as the basis (variable factor) for study, may reveal the most effective MANETs routing protocols for small, medium and large networks.

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