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Examining Possible Supplementary Nature of Routing Protocols in Mobile Ad-Hoc Networks (MANETs): A Discussion

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Abstract: Routing in Mobile Ad-hoc Networks (MANETs) is critical. As such, there are many routing protocols that have been proposed over the years. Each routing protocol has weaknesses and strengths. Currently, much of research on routing protocols in MANETs concentrate on literature reviews, performance comparison and proposition of new protocols. However, there has been very little or no attempt to examine the possibility of combining several routing protocols for effective routing in MANET. By highlighting the characteristics, strengths and weaknesses of eight routing protocols selected from the flat routing, hierarchical/hybrid routing and geographical position assisted routing protocols, this study attempts to establish whether different routing protocols in MANETs can be combined for effective routing. A hypothetical situation that uses a combined Zone Routing Protocol (ZRP) and Location-Aided Routing (LAR) for cluster networking is used for the sake of the proposition. This study refers to such protocol as ZRP-LAR driven. According to the findings from the literature review on MANETs routing protocols, this study establishes that it is possible to combine more than one routing protocols in MANETs to achieve effectiveness in packets transmission.

Key words: Mobile Ad-Hoc Networks (MANET), routing protocols, Zone Routing Protocol (ZRP), Location-Aided Protocol (LAR), clusters, flat routing

INTRODUCTION

Mobile Ad hoc Networks (MANETs) are composed of self-configuring mobile nodes linked through wireless connections (Rai *et al*., 2012). According to Rai *et al*. (2012) MANET's nodes that are adjacent to each other may transmit information between them while they depend on immediate nodes to pass 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. Because of this need-based trait of the MANETs, they have been highly applicable in the areas or situations that require momentary responses (Fig. 1).

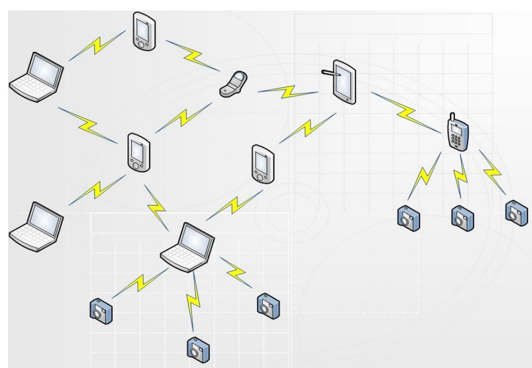

Fig. 1: Example of a MANET network

Short-lived responses do not call for the availability of permanent infrastructure, hence, making MANETs applicable solutions in emergency and combat zones (Hu, 2011). Because military rescue teams and battle groups deal with temporary occurrences requiring transitory actions, MANETs have been found to be highly effective systems of communication. Lately, however, MANETs have found more uses as wireless network advances.

It is characteristic of a Mobile Ad-hoc Networks (MANETs) to self-configure the mobile devices within the network. Wireless connections link these mobile devices. 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 (Singh *et al*., 2012). Some of the applications of MANETs include military deployment, responses to emergencies, deployment by the police force and development of virtual class rooms, among many more areas. For the last decade and half, MANETS has drawn the attention of researchers. Mainly, the researchers treat this area as a nascent field that require more research.

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. Due to their topological dynamism, MANETs experience several challenges, nonetheless. It is hard to predict these topological changes. 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.

Routing protocols examine the different ways of conducting/transmitting packets of data from the host nodes to the receiver nodes. A major challenge to the routing protocols for MANETs is their characteristic to constantly change topological makeups. Different and new nodes are formed as devices exit and enter the network. Efficiency of data and packet transmission within a system is mainly dependent on the type of the routing protocol. Routing protocols select the most capable route from the host terminal to the destination terminal.

There are many ways of categorizing routing protocols in MANETs. Using the topology of network for routing protocols, it is possible to develop both proactive and reactive routing protocols. While considering the strategy for communication deployed in the transmission of data packets from the sender terminal to receiver terminal, a unicast, broadcast and multicast routing can be developed (Verma and Soni, 2017). According to Verma and Soni (2017), MANETs routing protocols serve the purpose of outline the rules to transfer a data packet from the host node to the destination node.

Generally, routing protocols on MANETs can be classified either as table-driven or source-driven (Goswami *et al*., 2014). This classification is considered to conform to the routing strategy. Furthermore, MANETs routing protocols can be divided based on the network structure. From the network structure, MANETs routing protocols can be flat routing, hierarchical or aided by geographic information. Flat routing is in addition, made up of both the table-driven and the source-driven routing

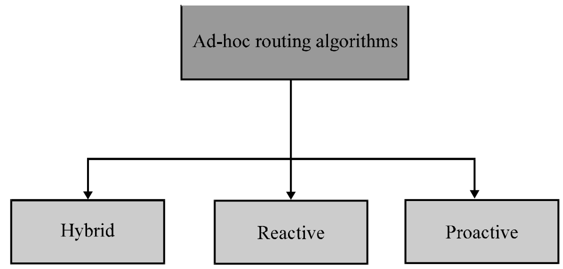

Fig. 2: MANET routing protocol classifications depending on design philosophy (Saeed *et al*., 2012)

protocols. Nonetheless, ad-hoc routing protocols fall largely within hybrid, reactive and proactive realms of routing protocols (Saeed *et al*., 2012) (Fig. 2).

In the proactive protocols, the routing information is maintained throughout the networks operation even in instances where the information in not required by particular network nodes. All nodes in proactive protocols possess the routing information of the peer nodes in the network. Proactive protocols use tables to store routing information regarding each of the nodes. Routing tables require occasional updating as nodes enter and leave the network. The link stage of routing serves as the main source of transmission rules for the proactive protocol. Not all transmission rules are similar in a proactive protocol. A transmission rule is determined by the routing information in an updated table. Additionally, proactive protocols may contain different routing tables (Gorantala, 2006).

Since, proactive protocols maintain routing information of all network nodes, it is inefficient and unsuitable for deployment in large networks. If a proactive protocol is used in a large network, it results into going beyond the routing information in the table. As a result, more bandwidth may be consumed. Reactive protocols, however, do not retain routing information on nodes in tables. In addition, reactive protocols do not maintain network activities. Reactive protocols formulate routing information upon demand. Packets and data are routed on-demand basis. Absence of routing tables in reactive networks means that destination nodes are identified by flooding the network with the packets and other data (Gorantala, 2006) (Fig. 3 and 4).

Hybrid routing protocols attempt to combine the advantages of both proactive and reactive routing protocols. Hybrid routing protocols are designed to minimize the overhead of proactive routing protocols as result of regular updates and maintenance of node's routing tables. Furthermore, the hybrid routing protocols assist in the minimization of latency in reactive routing

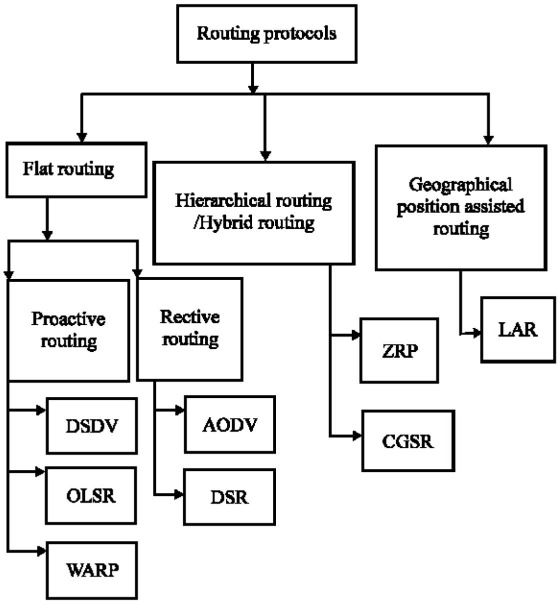

Fig. 3: Classification of MANET routing (Verma and Soni, 2017)

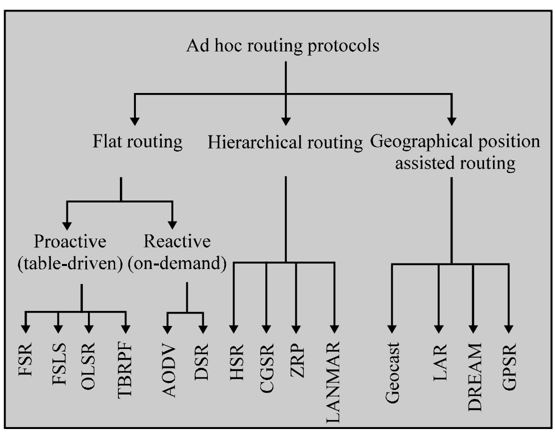

Fig. 4: Classification of ad hoc routing protocols (Hong *et al.*, 2002)

protocols (Vijayalakshmi and Sweatha, 2016). Route discovery tendency by the reactive protocols creates a slowdown latency, of packets delivery within a MANET network. Hierarchical routing is mainly deployed in larger networks. Hybrid routing protocols include Zone Routing Protocol (ZRP) and Cluster Switch Gateway Routing (CGSR).

According to Bang and Ramteke (2013), ad-hoc network systems are categorized into three generations. That is the first, the second and the third generations. Ad-hoc networks systems in use today are considered third generation. In 1970s, there was the first generation of ad-hoc networks. During 1970s, ad-hoc networks were known as the Packet Radio Networks (PRNET). PRNET was sponsored by the USA's Department of Defense conducted in the 70s. Later, PRNET was to develop into Survivable Adaptive Radio Networks (SURAN), an endeavor occurring in the early 1980s. Two ideas were incorporated in the creation of the PRNET. That is the Areal Locations of Hazardous Atmos-pheres (ALOHA () and the Carrier Sense Medium Access (CSMA) (Bang and Ramteke, 2013). ALOHA and the CSMA applies the idea of medium access control in conjunction with certain type of distance-vector routing protocol. Mainly, these two ideas were used in prototypes in the battle fields. Upon enhancing the PRNET, the Department of Defense created SURAN (Survivable Adaptive Radio Networks) in 1980s.

SURAN was able to support packet switching in a network in military combat environments that lacked good infrastructure. In 1980s, SURAN ad-hoc network ensured that radios would assume smaller size became less costly and more secure from attack. Consequently, these radio features augmented their utility. With the advent of affordable of personal computers and their wireless connectivity capabilities in the1990s, researchers opened up discussions on the possibility of commercializing ad-hoc networks. It is during this time that many conferences on networking began presenting research ideas on how to connect different terminals to form on-the-go networks. By the middle of 1990s, there had been proposals and development of several ad-hoc network protocols. MANETs took their current shape in the second half of 1990s. During this period, several MANETs routing protocols were developed. For instance, the IEEE 802.11 protocol was proposed and approved as medium access protocol. IEEE 802.11 protocol dealt with avoiding the collision of signals while at the same time allowing concealed terminals to connect to the network.

MANETs was all started by the Advanced Research Projects Agency (ARPA) in 1962 (Kumar, 2017). Based on a youtube lecture by Kumar (2017), the ARPANet was launched in 1969. The ARPANet first connected the University of Los Angelas at Santa Barbra and the University of Utah. Initially, MANETs were known as packet radio networks in 1970s. Packet radio networks were created by the Defense Advanced Research Projects Agency (DARPA) in 1970. Originally, packet radio networks ideas were used in the development of the first IP internet protocols. In 1980s, however, DARPA decided to develop the Survivable Radio Network (SURAN). By Kumar (2017) it is noted that in 1990s the creation of 802.11 occured. With the invention of affordable 802.11

radio cards, the personal computers became equipped with the capability of forming peer-to-peer networks. Presently, MANETs are mainly deployed for military use. For instance, MANETs are the basis for Joint Tactical Radio System (JTRS) and the Near Term Digital Radio (NTDR) systems used by the military.

Introduction of Personal Computers (PCs) and smart phones with their ability to conduct radio waves transmissions provided the ability to commercialize ad-hoc networks (Bakht, 2018). Afterwards researchers began presenting the possibility of collecting different terminals/nodes to form an affordable infrastructure-less networks. Such research proposals drew more attention on the development and deployment of ad-hoc networks. Bluetooth and ad-hoc sensors present the main applications of MANETs. A MANET can be made up of numerous sensors positioned in various points with a geographical area. Similarly, a hybrid ad-hoc networks is composed of several sensors spread within a geographical area. All sensors within the network must possess some smartness/intelligence and the ability to transmit signals within the network. Routing protocols within a MANET are responsible for identifying the notes that transmits and receives the signal. As a result of its adaptability, flexibility and dynamism, MANETs may be developed and deployed virtually in any environment (Beijar, 2002).

MANETs attack may take place in two major ways. That is either passively or actively. In passive attack, the data under transmission is not affected. Rather, passive attack pretends to be part of the data but with the sole motive of collecting important information (Kaur, 2016). A passive attack may be seen as planting an evil spy within a group of good guys with intention of stealing information. There is no disruption of routing while passive attack occurs. In an active attack, nonetheless, the transmission of data is interrupted. Compared to the passive attack, an active attack is more severe because the normal transmission of data between nodes is negatively affected, write (Kaur, 2016). Either of the types of attacks can emanate internally or externally.

Because MANETs depend on nodes for self reorganization, their network systems are more vulnerable to attacks than the wired networks. For this reason, securing MANETs can be a daunting task. But there are security objectives that must be pursued in MANETs to guarantee some safety for the users. Confidentiality should be always considered. Only the authorized devices and users are allowed to access the network to protect privacy and secrecy (Yadav and Uparosiya, 2014). Every node requires the capability to validate the ingenuity of the peer node and user. Valid network users and nodes need validation credentials to access the network. Authentication prevents imitators from accessing the network illegitimately.

Due to their vulnerability, researchers have developed numerous ways of fighting insecurity in MANETs. For instance, intrusion detection is a response scheme for detecting threats beforehand. Intrusion detection put forth both “Distributed and cooperative framework,” (Sheikh *et al.*, 2010) designed for sensing and identifying attacks. In the intrusion detection all nodes in a network are called to action. Once a node identifies a threat independently, it broadcasts a warning to the rest of the nodes (Sheikh *et al.*, 2010). But at times as a result of power limitation of the nodes, the dissemination of the warning may not be successful. Such incidents require cluster-driven instruction detection. Cluster-driven intrusion detection is designed in such a way that the network is divided into subgroups (clusters). Clusters enable the member nodes to disseminate attack warnings to the companion nodes. Intrusion detection role is assigned to a single node that serves as the watchman for others. Every time an attack is detected, the responsible node is expected to alert the rest of the nodes in the cluster. All nodes assigned to a cluster are served by one radio range.

Some other MANETs attacks include the wormhole. Packet leash is an attack response to the wormhole, observe (Sheikh *et al.*, 2010). Wormhole intercepts information under transmission in pretense of being a genuine receiver. The information intercepted is tunneled to another wormhole attacker. The intercepted information is corrupted by the wormhole and resent to the genuine receiver. Although, the message is disguised as valid, it carries hidden scripts designed to steal information or disable the line of transmission. Response to wormhole attack includes adding extra information to a packet to regulate the maximum distance of transmission this called packet leashing. Packet leashing can be either geographically bound or temporal bound. Geographically bound packet leashing uses the distance to regulate the transmission of a packet while temporal bound packet leashing deploys the maximum time of packet transmission.

Literature review: Notably, majority of research reviewed in this study regarding MANETs routing protocols concern themselves on three key approaches. That is, literature review, performance evaluation or proposition of new routing protocols. So far, no (or very little if any) research has been conducted to examine the possible complementary nature of MANETs routing protocols. Different scenarios calling for ad hoc network's response may need the deployment of wireless network's that utilizes more than one routing protocol. Every routing protocol has strengths and weaknesses, thus, scenario-based applicable. For example in battle fields, military communication can require the deployment of both Zone Routing Protocol (ZRP) and Location-Aided Routing (LAR) protocols for enhanced effectiveness of communication. In this instance, ZRP may be used for communication of nodes in a battalion while LAR may be useful in the inter-battalion communication due to the possible geographical that may exist.

An example of research that conducts comparison of MANETs routing protocols is (Alslaim *et al*., 2014; Anonymous, 2004). By Alslaim *et al*. (2014), the features, strengths and weaknesses of MANETs are highlighted. In the same research, the writers explore the characteristics of proactive and reactive routing protocols. Furthermore, the performance of DSDV, DSR and AODV is discussed and criticized. The inadequacy by Alslaim *et al*. (2014) is that it does not explore the possible supplementary nature of the routing protocols. Other studies such as Kohila and Gowthami (2015) compares reactive, proactive and hybrid routing protocols in tabulated manner. According to Kohila and Gowthami (2015) each routing protocol carries some level of limitations, hence, making it difficult to select protocols for given scenarios. The study notes, however, that every scenario requiring ad hoc network response is distinct.

Upon comparing the performance of two on-demand (DSR and AODV) and one table driven (DSDV) routing protocols, the writers observe that the MANETs routing protocols is a nascent field that will attract future research interest. Diverse performance parameters such as packet delivery ratio, end-to-end delay, routing overhead and throughput were compared by Kohila and Gowthami (2015). Based on the results from the research the two reactive protocols (DSR and AODV) performed better than DSDV. Comparing the three protocols, DSR outperformed the rest of two protocols apart from packet delay time from the source to the destination. Network Simulator 2 (NS2) was used to yield the results research (Anonymous, 2004, 2007) compared protocols AODV, OLSR and ZRP. Since, AODV and OLSR are equallyadopted for experimentation for RFCs by the IETF, the writers observe that perhaps, they are the most popular routing protocols in MANETs. Currently, there majority of research on MANETs routing protocols is being conducted by using the three routing protocols. Comparatively, however, ZRP is less used among the three routing protocols. Different from the other two routing protocols is largely viewed as a hybrid of protocols and as result, many researchers categorize it as a routing framework instead.

As noted earlier in this study, majority of research on MANETs routing protocols revolve around literature review, performance comparison and proposition of new routing protocols. By Alslaim *et al*. (2014), Kohila and Gowthami (2015), Hinds *et al*. (2013), a wireless spectrum enables peer-to-peer communication. Such a network can be used in the transmission and routingof packet data between neighboring nodes. Due to the wireless nature of packets transmission and the interdependence of the nodes, routing becomes critical. Study by Hinds *et al*. (2013) investigates a variety of routing protocols from simpler and more basic DSDV to a more complex MAODV. The study builds on the research of Perkins in an attempt to propose an advanced and effective routing protocol in MANETs. Upon reviewing the literature on AODV, MANETs and routing protocols, they propose a routing protocol that bases its ideas on Perkin's work. Reviewed literature indicated that AODV is the most popular MANET routing protocol. From the comparison of literature (Hinds *et al*., 2013) discovered that there is a limited deployment of the "random waypoint mobility model, excluding key metrics from simulation results and not comparing protocol performance against available alternatives".

Other research that presents a comparison of MANETs routing protocols include (Sharma *et al*., 2016). From the research by Sharma *et al*. (2016), uses the routing strategy to classify various routing protocols in MANETs in addition to highlighting their features. Consequently, the study reviews reactive, proactive and hybrid protocols. Nonetheless, the main concentration of the study revolves around DSDV, AODV, DSR, TORA, OLSR, WRP, DSDV routing protocols. Constructed from their research is the observation that no single routing protocol that is capable of being suitable in every scenario that demands ad hoc networks response. As stated by Sharma *et al*. (2011) the choice for a routing protocol must be based on the needs of a particular scenario. Future research need to establish ways of taking advantage of various routing protocols in MANETs to create a comprehensive, multifaceted routing protocols.

Performance of routing protocols in MANETs can be evaluated in relation to various mobility models. Study by Chavan *et al*. (2016) examines MANETs routing protocols under various mobility models occurring in different network areas. Covered in the study are the routing protocols DSR, DSDV and AODV. Every of the named routing protocols were studied RWP, GM and RPGM mobility model. By considering five networks and factoring their sizes by ten nodes incrementally, the prediction aspect was achieved. After the simulation of three parameters PDR, end to end delay and average throughput, RPGM mobility models outperformed the other mobility models. Furthermore, the RWP Model outperformed GM Model for majority of routing protocol blends such as protocol, mobility model, network area and number of nodes. "More such combinations can be studied in future (Chavan *et al*., 2016)".

Realizing efficiency and robustness in the design of MANETs routing protocolsis a hardmission, although, it is critical to the performance of the network. Owing to the dynamic nature of MANETs networks, robustness of routing protocols is very essential (Natarajan and Mahadevan, 2017). Every proposed routing protocol in MANETs is determined by a particular scenario or environment. For this reason, no MANET routing protocol is similar to another. Because every routing protocol is different, evaluation of performance can be used to determine suitability in various scenarios.

By Natarajan and Mahadevan (2017) it is noted that determining the performance of a routing protocol is very critical. Simulation is used by Natarajan and Mahadevan (2017) to determine the routing performance of selected protocols from proactive, reactive and hybridcategories. Through simulation, data is obtained for considerations in various environments. Evaluations of the performance of AODV, DSR, LAR, DSDV, OLSR, FSR and ZRP protocols were conducted. The simulations were designed to relate to reality as much as possible. Network parameters such as node density, dynamic topology and traffic were considered for simulation on Network Simulator 2 (NS2). The simulation results indicate that the identified network parameters impact the routing protocol performance. Moreover, the research indicated that a single routing protocol is incapable of being suitable for every scenario. Since, a single routing protocol is inadequate to address the needs for all imagined networks situations, the study advices that some research be conducted to establish the possibilities of more robust routing protocols. Under TCP protocol, DSDV displays better performance regardless of speed.

By varying selected network parameters (Hanji and Shettar, 2014) evaluated performance of the three routing protocols. From the simulation results, the performance lowers with the increase in the number of nodes and the time of simulation. When the size of a network enlarges, the broadcast goes up, hence, the transmission of data packet from the source node to the destination node becomes dependent on the performance of the intermediate node. The simulation results indicate that AODV and DSR outperform DSDV. For example, the energy consumption resultsreveal that comparatively, DSR require less energy than the other two routing protocols. Overhead generation in AODV protocol is comparatively high. Although, DSDV generates considerable routing overhead, its topology changes as packets hop from one node to another. Due to the deployments of several routes and the lack of periodic updates, DSR generates the least routing overhead. When is simulated for PDR for DSR it achieves the best packet delivery ratio. If the number of nodes is increased as the time of simulation increases, AODV and DSDV experience lower PDR ratio (Hanji and Shettar, 2014). In the opening stages of the simulation, the packets dropped in AODV andDSDV are minimal, then surges steadily with time.

Additional studies of Lalar and Yadav (2017) and Nayak *et al*. (2013) inspect MANETs routing protocols through comparison of their characteristics, strengths and weaknesses. Firstly, the routing protocols are divided into proactive or table-driven, reactive or on-demand and hybrid routing protocols. Selected routing protocols from the stated three categories are selected for the comparative study. The studies established that all routing protocols are distinct in their features. Mainly, routing protocols are differentiated by the method used in the determination of routes in a network. Study by Lalar and Yadav (2017) selected DSDV, CSGR, WRP, AODV, OLSR, DSR, TORA, ZRP, ZHLS, DYMO routing protocols for comparison. The features compared included "protocol type, routing approaches, routing structure, route selection, route, routing table, route maintenance, operation of protocols, advantages, limitation" (Lalar and Yadav, 2017). By Nayak *et al*. (2013) compares certain conventional routing protocols in MANETs. Nayak, Balwaik and Sarwade (Nayak *et al*., 2013) use characteristics such as common usage, routing protocol algorithms, advantages and limitations as features for their comparison study. Finally, Nayak *et al*. (2013) suggests that future research may utilize the understanding of these features for the creation of better routing protocols.

MATERIALS AND METHODS

The purpose of this study is to determine the possibility of combining more than one routing protocols to enhance the transmission of data packets in a MANET network. To establish the likely supplementary behavior

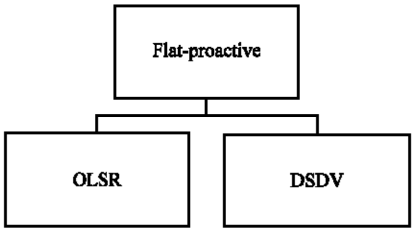

Fig. 5: Flat-proactive selected category

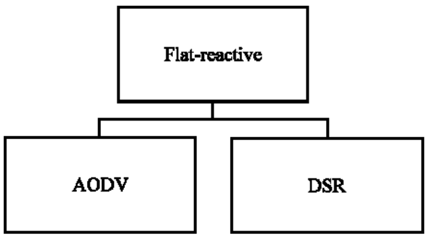

Fig. 6: Flat-reactive selected category

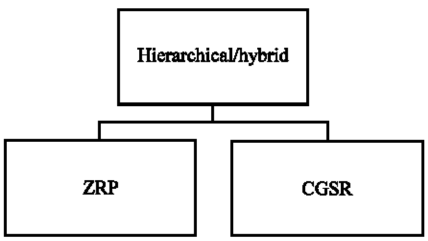

Fig. 7: Hierarchical/hybrid selected category

of the MANETs routing protocols, eight routing protocols from the routing categories highlighted by Saeed *et al.* (2012),Verma and Soni (2017) and Hong *et al.* (2002) are selected. From each of the categories, two routing protocols are selected randomly. Consequently, this study selects OLSR and DSDV to represent flat-proactive category while AODV and DSR are selected to represent flat-reactive category. Markedly, nonetheless, if a routing protocol appear in two of the three selected categorizations (Saeed *et al.*, 2012; Verma and Soni, 2017; Hong *et al.*, 2002) is selected automatically. The other routing protocol is selected randomly.

Accordingly, AODV and DSR are selected to represent flat-reactive routing protocols (Fig. 5) while ZRP and CGSR are selected in this study for hierarchical/hybrid routing protocols (Fig. 6). In Fig. 7, LAR and GPSR are selected to for geographic location assisted routing protocols (Fig. 8).

Upon selecting the eight routing protocols from the four identified categories, this study highlights their best suited scenario of uses, their weaknesses and strengths.

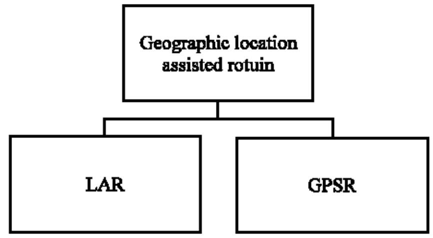

Fig. 8: Geographic Location assisted routing selected category

After reviewing the stated characteristics, a tabulated comparison is drawn in attempt to establish possible areas of complements and supplements of the routing protocols.

Selected flat-proactive routing protocols: To represent the flat-proactive routing protocols we selected OLSR and DSDV. By Flathagen (2008) OLSR is defined as “protocol that makes its nodes to exchange their link state messages periodically in order to maintain the topology information”. Moreover, OLSR uses three types of control messages in its data packets transmission. The control messages include the Hello messages also known as neighborhood messages, the topology messages also known as Topology Control (TC messages and Multiple Interface Declaration (MID). According to Tokekar and Joshi (2011) the reliability of optimized link state routing protocol in data packets propagation is based on link state algorithm. State link algorithm is proactive meaning, there is stable supply of routes’ information upon request by nodes.

The Optimized Link State Routing (OLSR) enhances the “classical link state algorithm tailored to the requirements of a mobile wireless LAN” (Jacquet *et al.*, 2001). OLSR utilizes the Multipoint Relays (MPRs) idea in data packets propagation within a network. This routing protocol enhances data transmission because it cuts the message overhead by avoiding involving nodes that are not necessary in data transmission. To achieve this, selected nodes (MPRs) are deployed in the messages broadcast in a network. MPRs ensures that message broadcasting does not call for every node in a network. Furthermore, MPRs are the only network nodes that are involved in the generation of link state information. Secondly, added optimization in OLSR is realized through reduction of the number of link state messages that are broadcast in the network (Jacquet *et al.*, 2001). Thirdly, to augment optimization further, the member nodes of MPR are allowed to confine their roles to only transmitting link state messages to the members of the MPR. The idea of permitting a node to confine their roles to only the member MPRs, introduces partial propagation in a network, an idea not found in the traditional routing protocols.

In report of Jacquet *et al*. (2001) it is noted that OLSR is best applied for networks that serve large areas, hence, requiring dense inter-connections and more mobile devices. This feature is enabled by the MPR concept. Similar to Open shortest path first, OLSR can be viewed as an optimization of pure link state routing protocol.

DSDV is a proactive routing protocol that depends on the network information that is stored in a table. In this routing protocol, every node maintains a table containing the information about the network (Naseem and Kumar, 2013). Entries in the routing tables include the destination's address, the next hop toward destination, the number of hops required to reach destination and the sequence number at destination node. A routing table keeps the highlighted information regarding every node in a network. DSDV operates on the principles of the Routing Information Protocol (RIP. In RIP, every node sustains a routing table that in turn retains information on potential destinations of messages and the number of hops necessary to deliver the messages within the network. Since, DSDV deploys the concept of distance vector routing, it is bidirectional links. However, DSDV is limited in the sense that it offersa single route for a source/destination pair.

To guarantee the up-to-date information in tables, there is continual exchange of the stored information among the nodes. Information stored in routing tables changes as a result of the dynamism in mobile ad hoc networks. These exchanges are dependent on the neighbor-to-neighbor hops. Based on lecture of Narra *et al*. (2011) shared table information is classified into three categories. That is the immediate advertisement, incremental updates and full dump update. Addition of new mobile devices creates new routes while the exit of mobile devices may cause link breakages. Furthermore, metrics in terms of power, range and area can change. These changes demand immediate updates of the information in the neighboring nodes.

According to He (2002) and Ahmed *et al*. (2012) every change in the stored information is promptly propagated to the neighboring nodes. Progressive updates of the table information are carried out between full dump to enable limitedupdatesin the tables. Steady increment of the updates in tables are measured in single Network Data Packet Unit (NDPU). Updates of the tables comprehensively is either done in steps or in wholeness in instances that involve significant change in the topological information. Full updates call for the deployment of multiple NDPUs. Updates of table information are provoked by a node in the network that has an assigned bigger number than the source. Such numbers are sequenced. A node has the option to consider or rejects the requested updates based on the table sequence number. Breakages in the network invoke the involved nodes to update the rest of the nodes regarding the topological network information about the availability of the break. Infinity is assigned to the broken link (unlike the actual numbers in the rest). For normal updates messages, a node uses an even sequence number while odd numbers are deployed during the breakage in the network link.

Selected flat-reactive routing protocols: Essentially, the Ad Hoc On-demand Distance Vector (AODV) was created for use in mobile ad hoc wireless networks (Anonymous, 2018a-d). Similar to other reactive routing protocols, AODV only initiates routes creation between the source and destination nodes when the action required. In addition, AODV has the ability to support both unicasting and multicasting of data packets in an ad hoc network. According to Anonymous (2018a-d), AODV protocol was realized as a joint effort by Nokia Research Center, the University of California, Santa Barbara and the University of Cincinnati in 1991.

Since, AODV protocol establishes routes only on demand by the source nodes, its algorithm is regarded as an on-demand. As such, AODV does not result into unnecessary overheads. The established routes remain useful only if they are necessary in the inter-nodal communication propagation of data packets between the established links. When multicasting is necessary in a network, the nodes results to formation of trees. AODV deploys sequence numbers to ensure that routes remain fresh. Regardless the number of nodes in a network, AODV enables internal regulation in links creation by avoiding loops. In AODV based networks, operations are not active until connections among nodes are initiated. Nodes that are activated for connections send message around the network in form of a request. While propagating the request message, every node that receives it notes the identification of the node. This process results into temporary routes between the sources nodes and the destination nodes.

Rouse (2007) defines Dynamic Source Routing (DSR) as a "self-maintaining routing protocol for wireless networks". DSR protocol may be deployed in both cellular and ad hoc mobile networks that compose around 200 nodes. A dynamic source routing network does not call for human intervention, since, it is dynamic. That is it can configure and organize itself autonomously devoid of human oversight. Every source noderegulates by decision, on which routeto establish a connection to destination nodes. According to Johnson *et al.* (2001), Anand and Aggarwal (2013), Awerbuch and Mishra, (2016) DSR is made up two vital components. The components are known as the route discovery and route maintenance. Route discovery elects the ideal path for a broadcasting packet data from the source node to the destination node. Route maintenance guarantees consistency in the packets transmission. To ensure the consistency, the route maintenance eliminates looping in the network despite the changes in the network. The changes in a network occur as a result of the mobile devices joining and leaving the network.

Examples of DSR based transmission protocols include the Link Quality Source Routing (LQSR) developed by Microsoft. This routing protocol is designed to work with Microsoft technologies that depend on Mesh Connectivity Layer (MCL) (Rouse, 2007). Mesh connectivity layer enables computing devices to connect in wireless mesh networks. The standards useful in such connections include WiFi and WiMax.

Selected hierarchical/hybrid routing protocols: Zone Routing Protocol (ZRP) was suggested by Haas and Pearlman. 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 take 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 (Gupta *et al.*, 2011). 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 from (Fig. 9).

In Fig. 4, node S has radius of 2 hops. Peripheral nodes are the nodes whose location is exactly 2 hops from node S. In the provided example, nodes G, H, J and K are peripheral nodes. Node K is more than 2 hops from node S, hence, not a member of the zone. All packets transmission within the routing zone is carried out proactively while reactive routing is relied upon to transmit from zone S to node K.

Strictly speaking, ZRP should be viewed as a framework of routing protocols than a protocol. It is possible to control the number of nodes in zone by regulating the transmission power of nodes. If nodes in a

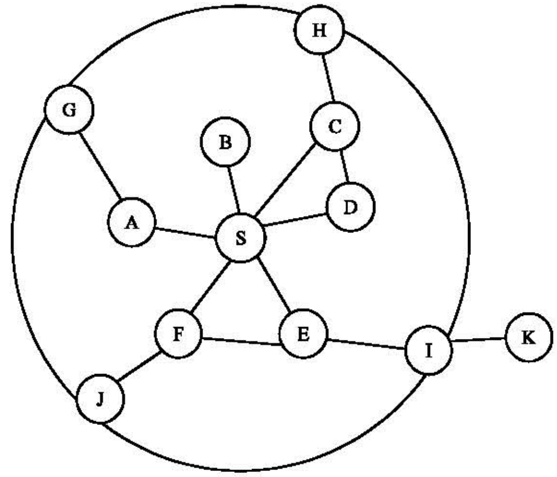

Fig. 9: An example of a routing zone with radius = 2 hops (Beijar, 2002)

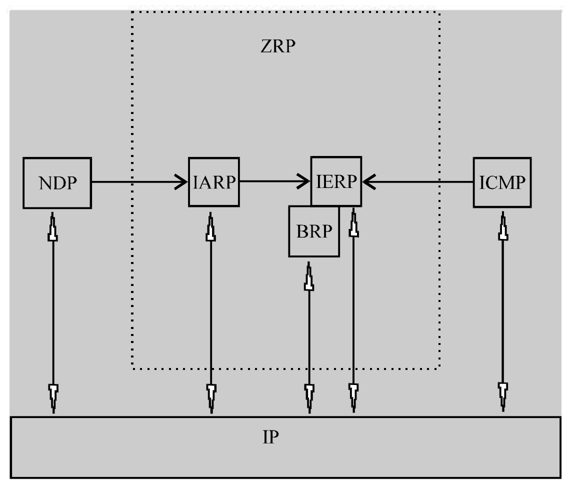

Fig. 10: ZRP components (Anonymous, 2018a-d)

zone are adjusted to lower power mode, the number of nodes that can communicate directly to the node goes down. The opposite is true. A zone whose radius is too large, leads into coverage of additional nodes. Such instances result into extra overheads because of the increase of updates of routing tables. Large zones can also bring about congestion and collision of packets in a network.

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 regulated by IARP while IERP border casts routing requests to the peripheral nodes (Fig. 10).

Another hierarchical-hybrid routing protocol is the Cluster-head Gateway Switch Routing (CGSR) (Raza *et al.*, 2010). CGSR is a hierarchical routing structure

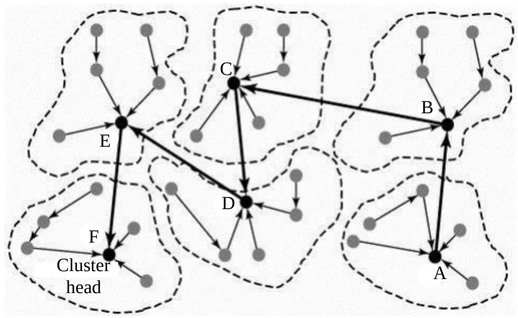

Fig. 11: Communication with cluster-head Gateway Switch Routing (CGSR) protocol

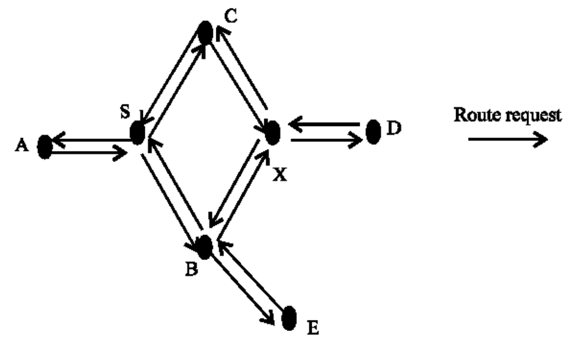

Fig. 12: An example of flooding in LAR (Ko and Vaidya, 1998)

supporting limited harmonization and synchronization among cluster nodes through determination of cluster-heads. Dalvi (2015) notes that CGSR assumes a somewhat indolent approach to routing compared to other routing protocols. Unlike the table-driven routing protocols, not every node that maintains up-to-date routes. Conversely, routing paths are established on demand. Once a source nodeneeds to transmit packets to a destination, it appeals to the routes establishment procedures in the network for path discovery to the destination. The usability of a route stays viable till there is a successful packet transmission a packet has been delivered to the destination node or when the route expires.

This routing protocol is disadvantageous because the length of the route can elongate, thus, augmented instability in the system as nodes move, join and leave the network. This instability results from the frequent changes in the cluster-heads in cases where there is removal or additional of cluster heads. According to Anonymous (2007, 2018a-d) and Dalvi (2015), CGSR experiences high power constraint as a result of high rate of power consumption at the cluster heads, in comparison to the rest of the network nodes. Path breakage is also a concern because there is an almost constant possibility of changes of the cluster heads.

Cluster routing means that a node isobligated to determine the optimalpaththrough the cluster heads as listed in the cluster-member table Anonymous (2018a-d). In Fig. 10, six clusters are used to demonstrate how cluster heads are created. From the Fig. 11, a node in cluster A propagates a data packet to a node located in cluster F. Member nodes only transmit packets among themselves while the cluster heads enable inter-cluster propagation of packets. Nodes in cluster send packets in hops. That is nodes in cluster depend on table entries in packets routing. Cluster heads propagate packets via. other cluster heads till the destination is reached (Fig. 11).

By Dalvi (2015), Cluster-Head Gateway Switch Routing (CGSR) protocolis table-driven. Clusters are composed of predetermined number of nodes that are governed by cluster head. Designation of a node as a cluster head is accomplished through the application of a distributed clustering algorithm. Nevertheless, a cluster head may change based on several reasons. For instance, a cluster head can be changed as a result of unsustainable fluctuation in power. If a node labelled as cluster head exits a network, it replacement is justified. There are two tables maintained by CGSR. The first table is known as the cluster-member while the second table is dubbed routing. The recording of every cluster head of the destination node occurs at the cluster-member table. Hops to each destination is maintained by the routing table. Similar to DSDV protocol, every node keeps its tables cluster-member table, up to date upon reception of new information from the fellow cluster members (Moltchanov, 2009).

Selected geographic location assisted routing category: Location-Aided Routing (LAR) protocol, unlike the topology-based routing protocols, depend on knowing the physical position of nodes for its communications. In LAR, the position of a node is determined through GPS or some other services capable of identifying the position. Data packets are transmitted to the position of a node or the area surrounding a node. The additional information in the LAR gets rids of some of the shortcomings of topology-based routing protocols. All physical positions of the nodes participating in a network are necessary (Fig. 12).

Location-Aided Routing (LAR) was initially proposed by Ko and Vaidya (1998). In their study, Ko and Vaidya (1998) propose a routing protocol that considers location information in the distribution of data packets. Global Positioning Systems (GPS) provides the necessary geographical information for the LAR. They contend that due to the utilization of geographical information of ad hoc network nodes, LAR augments the efficiency of the

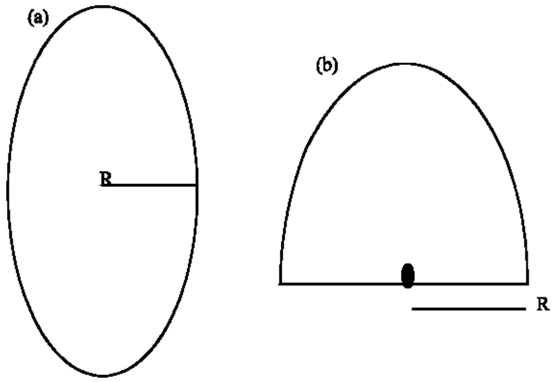

Fig. 13: Sample request zones in LAR: a) Possible request zone without LAR and b) Possibel request zone with LAR

routing protocol by introducing "Request zone". LAR's main purpose is to improve on routing protocols that deploy flooding of packets within the networks as a way of packet routing particularly, the Dynamic Source Routing (DSR).

Positioning of possible location and direction of a node is vital in LAR. Direction of a node's movement, for example, reduces the size of a possible request zone. Assume that node N intends to forward some data packet to node S. Without the information on the direction of movement, the request zone becomes the are covered by radius R. Assuming that a node is moving away from the destination at an average speed of v and an initial time t_0 and current time t_1 , then, $R = v(t_1-t_0)$. The direction of the node's movement reduces the request zone by half. Supposing that the direction of node S is moving, in approximation towards North of N (Fig. 13).

Similar to both the AODV and DSR, LAR propagates data packets on demand basis (Husain *et al*., 2010). According to Husain *et al.* (2010), LAR reduces routing overhead due to the ability to use location information in routing. Flooding of data packet is method data information distribution in both the DSR and LAR. Accordingly, the algorithm used in the LAR necessitates the sender node possess the ability to determine the possibility of a receive node is a request zone. Location Aided Routing (LAR) applies "directional forwarding flooding" (Mikki, 2009) in rout discovery.

A MANET that deploys LAR may use a "directional antenna or GPS system to estimate its (x, y) position" (Mikki, 2009). By deploying GPS, each node gets assigned coordinates in the form of (x, y). GPS also defines the angular position of a particular node in relation to another. For example, assuming that the coordinate position of sender node A is (x_1,y_1) and destination node B is (x_2,y_2) then: The distance between the two is:

$$d = \sqrt{(x_2-x_1)^2+(y_2-y_1)^2}$$

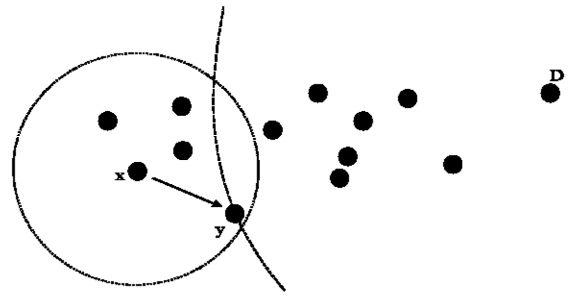

Fig. 14: Greedy forwarding example. y is x's closest neighbor to D (Karp and Kung, 2000)

Nodal distance formula (Mikki, 2009): The angular position is determined by the equation:

$$\theta = \tan^{-1}\frac{(y_2-y_1)}{(x_2-x_1)}$$

Nodal angular determination formula (Mikki, 2009): Directional antennae use the Angle of Arrival (AoA) in determining the angular position of destination node, according to Mikki (2009). Signal strength is very vital in determining the distance between two nodes while the angular formula.

Karp and Kung (2000) presented Greedy Perimeter Stateless Routing (GPSR) protocol that considers the positions of both the routers and the destination nodes in routing paths discovery. According to GPSR, a decision to forward a packet is decided upon best if the position of the routers and the destination are known. Karp and Kung call it a "Novel routing protocol for wireless datagram networks that uses the positions of routers and a packet's destination to make packet forwarding decisions". In GPSR, the information of the immediate nodes to the router is used in greedy transmission of packets across the topology of a network. Once the limit of greedy transmission is reached, GPSR uses an algorithm to traverse the edges of a network. Comparatively as the number of destinations increase, GPSR "scales better in per-router state than shortest-path and ad-hoc routing protocols", since, it keeps the state of the local topology of a network only. Because mobile ad hoc networks are dynamic devices are very mobile, the topology of such networks are likely to change. However, GPSR responds to these changes in topology by utilizing local topological information for routing pathfinding. After an extensive simulation of mobile wireless networks, Karp and Kung (2000) concluded that GPSR is applicable in areas that use dense wireless networks (Fig. 14).

GPSR permits nodes to determine by use of beacons, their closest neighbors (Anonymous, 2018a-d). The greedy algorithm is meant to discover the closest path to the destination. GPSR utilizes a greedy forwarding algorithm for the shortest path calculation. If an optimal path the shortest and most efficient path, is calculated, it is used to transmit the packet to an intended destination. In case the greedy forwarding flops, GPSR uses perimeter forwarding in route discovery. For GPSR to use greedy forwarding algorithm, the routers source nodes, need to first identify their own locations. By identifying their own location, the greedy forwarding algorithm calculates the shortest route to the destination node. According to Balci, GPSR is a "Responsive and efficient routing protocol for mobile, wireless networks GPSR can be applied to sensor networks, rooftop networks, vehicular networks and ad-hoc networks".

RESULTS AND DISCUSSION

ZRP-LAR supplemented ad hoc network; A hypothetical scenario: Clustering in ad hoc networks involves dividing a network into interconnect subnetworks. Within each cluster, a node is selected to serve as the head/controller. Such a node is referred to as the Cluster Head (CH). Selection of a cluster head is based on some metric or a combination of metrics such as power, degree, identity, mobility or weight (Bentaleb *et al*., 2013). Cluster coordination is the main role of a cluster head.ad hoc network clusters are also made up of gateways and member nodes. Communication of different clusters is carried regulated and coordinated by the gateway nodes.

Nodes that are neither heads nor gateways are labeled as members. Dana *et al*. (2008) observe that a node in a cluster exists independently of the nodes in other clusters in a network. Clusters in the proposed MANET may be equated to single classrooms or schools in a slum area. Mobile nodes can be considered as the learning participants. Within a cluster, the range of each mobile device is gauged to determine which becomes the cluster head, the gateways and the members.

By considering the range size of a node, the other two metrics (distance and cluster size) are automatically included. According to AGI Global website, transmission range is "defined by the maximum distance a node can send its data to," ("What is Transmission range", n.d). This implies the following:

Transmission power is directly proportional to the transmission distance assuming transmission power of a node = p and transmission distance of the node = d Therefore, power (x) needed per unit distance by a node is x = p/d.

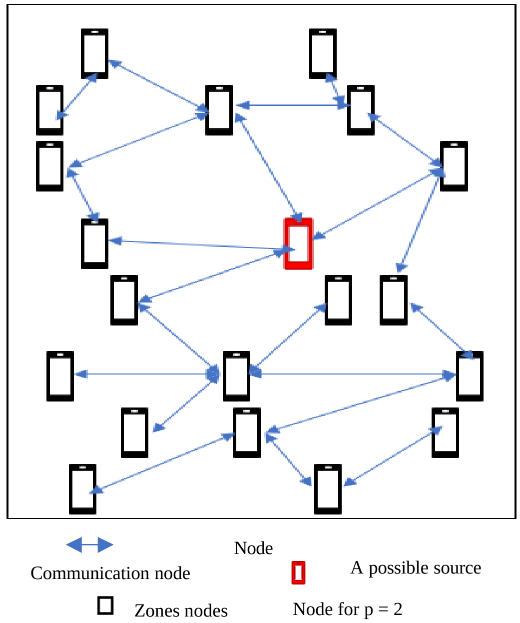

Fig. 15: Proposed cluster without a cluster head or a gateway

Because in the proposed MANET network is composed of classrooms as clusters, there must be a distance between each of the classrooms. The cluster head may be used as the reference node for determining the transmission power of gateway node (Fig. 15).

For example, if the transmission power of the cluster head is h and the average distance between it and the cluster gateways = g and the distance average distance between clusters = c, then the possible transmission power (p) of the gateway; p = ch/g.

The routing protocols proposed for MANETs, so far, consider a limited geographical space. For example, every MANET routing protocol proposed in the literature is only applicable in particular situations that call for immediate response. Events that demand the transmission of data packets across large geographical areas such as cities cannot be adequately addressed by the existing routing protocols. As a result of this shortcoming, this study combines the advantages of both ZRP and LAR for the transmission of data packets in large geographical areas (Fig. 16-18).

Upon briefly reviewing the literature on selected routing protocols, the author randomly selected Location-Aided Routing (LAR) from geographic location assisted routing protocols and Zone Routing Protocol (ZRP) from hierarchical/hybrid routing protocols. This section outlines and discusses the possibility of creating

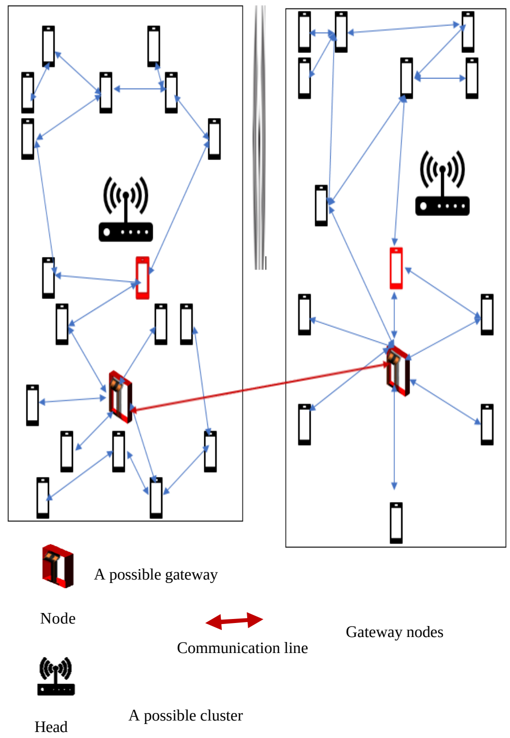

Fig. 16: Proposed cluster without a cluster head or a gateway

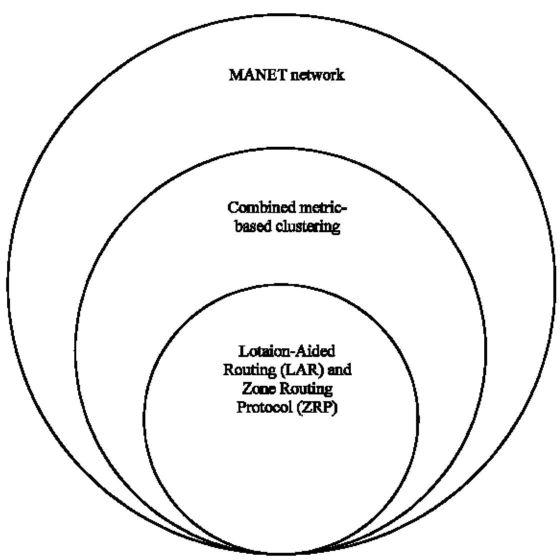

Fig. 17: Proposed learning resources sharing MANET network main pillars

a MANET for sharing learning resources between the well-resourced private schools and the marginalized slum schools in a slum. Zone Routing Protocol (ZRP) and the

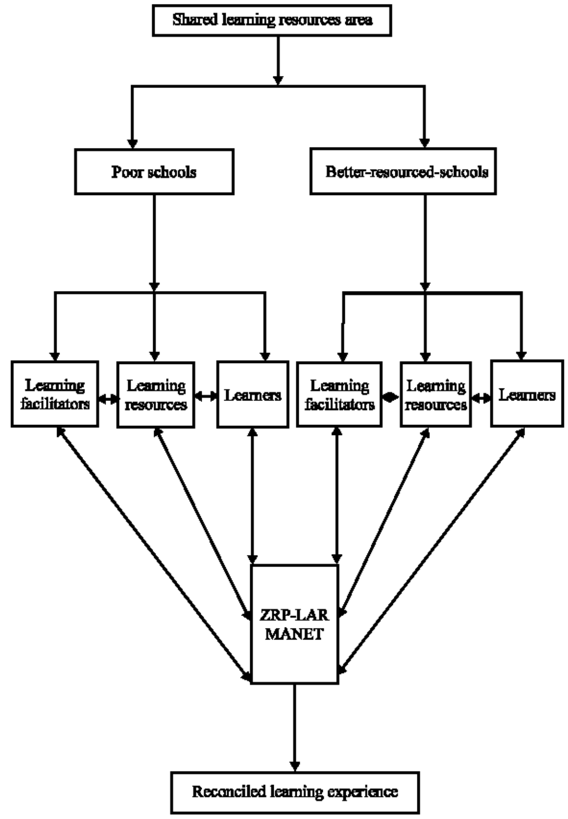

Fig. 18: Proposed learning resources sharing model based on ZRP-LAR routing protocols

combined metric-based clustering are suggested as underlying guide to such a system. You may think of them as the main pillars of the proposed MANET network. Within the ZRP routing zones, it suggested that the furthest peripheral nodes of a cluster should be determined based on the following:

- Distance between the clusters all mobile nodes in a classroom
- The average power/energy of the nodes in cluster
- Cluster size. That is the number of nodes in a cluster

CONCLUSION

Upon analyzing the studies of routing protocols in MANETs, this study establishes and concludes that there is a possibility of combining more than one routing protocols to achieve effective data packets transmission. According to the features algorithms, strengths and weaknesses, of MANETs routing protocols, there is a possibility of combining more than one routing protocols for routing in different scenarios. For instance, it is possible to use ZRP-LAR for MANET routing in a scenario that involves packet transmission between two environments separated geographically. In such a scenario, ZRP would be used for zonal routing while LAR can be deployed for inter-zonal routing.

It is noteworthy, however, that this study does not cover to exhaustion the minute details that should be availed to make such a project feasible. For such a network to become a reality, we must acknowledge that there are several factors that need to come to play. For example, there should be political, economic and social good will from the stakeholders if the network is to become a success. Such factors are beyond the scope of this study. In addition, there should be more research done to establish the viability of such network and the accompanying security issues and possible network failures.

RECOMMENDATIONS

The proposed MANET network requires further research particularly on its reliability. For network to effectively enable the sharing of learning information between schools, it requires to have the ability to be steady in it services and modes of operation. Survivability of the network is also an issue that requires some further exploration. Because technology changes rapidly, it is important that a network does not become outdated shortly after installation. In other words, the network's design must be futuristic. Manageability is also another area of the network that may require more investigation. Being able to manage a network is very critical in its service delivery to the clients. For example, it is very vital for the network administrators to be able to quickly identify network issues and respond to them on time for consistency in services provision.

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