Implementation of DHT-Based Routing in Smart Grid

Zia Ur Rehman, Dr. Nadir Shah, Habib Ur Rehman and Sehrish Kashan

***Abstract*— By integrating traditional power grid with information communication technology (ICT), it is referred as smart grid. Power line communication (PLC) technology can be used for communication purpose in smart grid. Recently, distributed hash table (DHT)-based routing protocols are proposed for mobile ad hoc network (MANETs) which aims to avoid flooding in route discovery. In this study, we show through examples the limitations of existing routing protocol (e.g. Opportunistic Routing (OR)) proposed for smart grid. Then we propose how DHT-based routing can improve the performance of smart grid in comparison to existing routing protocol.**

***Keywords*— Distributed Hash Table, Power Line Communication, Smart Grid.**

I. Introduction

Smart grid is the integration of power grid infrastructure and information communication technology (ICT) to provide auto management and control of power grid. Power lines of smart grid can also be used for communication purpose by using power line communication (PLC) technology [1].

The smart grid technology definition depends upon the area or environment in which SG would operate and the communication channels and other requires technologies are essential to consider while defining SG. But in case of no definition everyone looks by their own perspective and several assumptions are there to account. Literature cited in [2], [3] provides different definitions regarding SG. Taking the definition of ECTF (European Commission Task Force) on SG provides a comprehensive and working definition of SG that is Smart Grid is a network where the electricity network is used as medium to connect and integrate intelligently the nodes connected to it. The contributors involves both consumers as well as generators. SG ensures a power system that is maintainable and efficient in terms of economy. SG also provides secure data transmission with greater quality and less chance of data wastage. SG is the communication system where the communication technologies are working in collaboration with electric generation, and transmission of data where the user or consumer can manage its data usage and can choose the data usage offer that is economically suitable for the consumer [4].

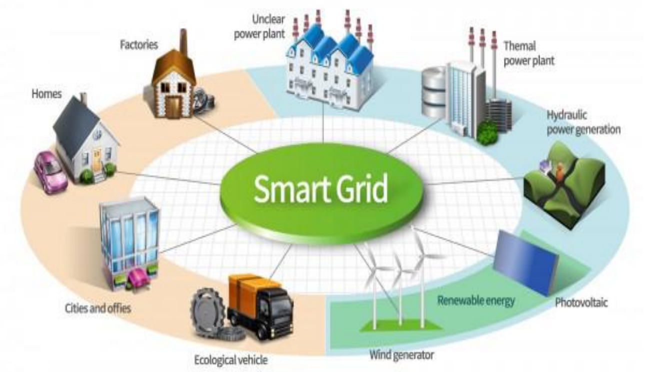

Fig. 1 Conceptual model of Smart Grid

II. Review of Literature

Routing in smart grid is required on several levels including grid station, substations, and transformers and also inside customer premises. Routing is as much important in smart grid as it is in the telephone line communication system. To implement routing in smart grid the understanding of communication network id essential. Hence detail and design issues are need to be concerned before implementing routing in smart grid technologies.

A. Power Line Communication

A network that comprises with the communication capability of holding the alternating current and communication data as the same time, so the electric lines does not disturb the data packet communication is called power line communication (PLC). Communication technologies are needed for the digital subscriber line, this requires the existing power line networking [5].

Broadband can be provided on power lines and different communication technologies are required for this information transmission process. PLC technologies may vary from the inside premises wiring to the other distribution media for the network. The internet access and the packet transformation process used the existing typical transformers because the avoid broadcasting of signals. And power line communication demands various protocols to work with different signal frequency as well as the different data transmission rates. Further to make communication available

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to lager network the complex sort of technologies are required [6].

Communication problems those occur in the power line communication are almost similar to the problems those occur in wireless communication. Radio signals the congestion environment could cause the signal distortion that is the case where radio devices are not in proper spectrum [7], [8].

There are several advantages to PLC based communication major of them is ubiquity which means that every building and house requires power communication lines and now after implementing this technology we do not require to use additional media for data communication because the same electric wiring would be used for data communication as well as electric power supply. Other advantages to this technology are:

- PLC based communication uses the existing infrastructure of the electric supply that will cover the entire country as well as the entire world.
- Easy organization or deployment.
- No additional wiring is required for data communication.
- No use of robust encryption method [9], [10].

Based on these advantages, our focus in this study is on PLC-based communication system for smart grid.

B. Existing PLC-Based Routing in Smart Grid

PLC based routing in smart grid allows control of both power and data communication. PLC routing offers many benefits in terms of using the existing infrastructure of telephone lines. PLC based communication routing involves certain levels of security for data transmission and reduce the possibility of redundant information. PLC based routing faces several other challenges because changes occur when any node is turned on or turned off which could imbalance the sender, receiver or the power line. These changes only associated to the node but can affect the communication therefore asymmetric links can occur in between the nodes. Hence response time connectivity and reliability in the PLC based routing are needed to be addressed PLC based routing in smart grid [11].

C. Opportunistic Routing for Smart Grid using PLC

Opportunistic Routing (OR) improves the network performance by achieving wireless network's broadcast nature in sensor and ad hoc networks. Traditional routing, sequential routing and opportunistic routing differ when the data is to be forwarded as an intermediate node. In sequential routing predetermined intermediate nodes decided before even transmission begins and a dedicated node is selected to transmit the information. In OR a forward set is used, forward set consists of multiple intermediate nodes. This forward set overhear the transmitted information from the sender [12]. However the node closest to the destination broadcasts it, this continuous until packet reaches to destination. Major improvement introduced by OR such as reliability and end-to-end delay throughput these characteristics improves network performance as compare to the traditional sequential routing mechanisms. Opportunistic routing is considered as a good nominee for PLC-Access Network because of the unique characteristics of power line PLC signals. Feasibility of OR in PLC is emphasized in this particular research, and a customized OR is proposed for this purpose and named as PLC-OR [13].

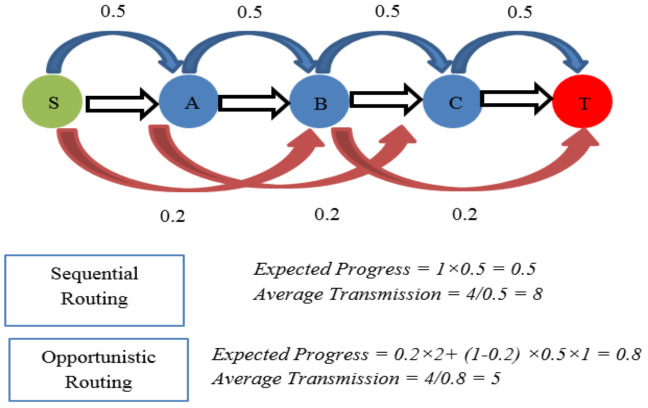

Fig. 2 OR and Sequential Routing in terms of Expected Progress

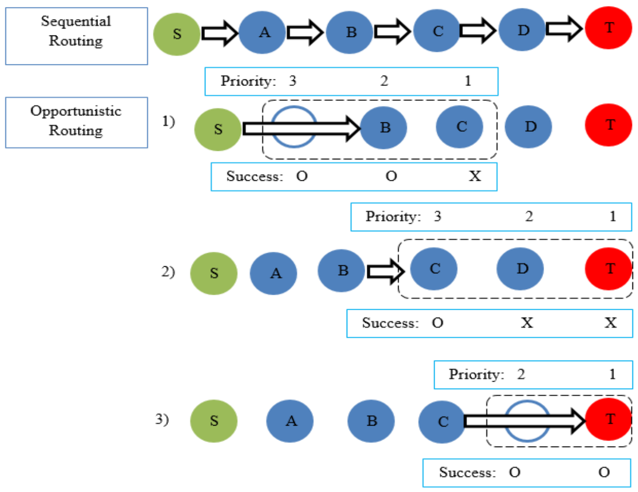

Fig. 3 Opportunistic Routing in a Linear Topology

In example shown above the sequential routing requires five transmission towards destination but Opportunistic routing requires only five transmissions for packet transmission. Hence opportunistic routing requires less number of transmissions tan sequential routing [13], [14].

D. Automated Channel and Performance Measurements for Power Lines

For automated measurement techniques critical characteristics of the system has to be selected, thus the measurement can be analyzed in limited effort because the channel behavior is not much complicated. Search algorithm for small bands is used to analyze the automated measurement for this purpose oscilloscope function is used this function also allows the offline verification of data. Noise analysis algorithms are also used to calculate absolute values with the help of the automated measurement techniques. Automated measurement techniques also helps in providing high resolution images for the measurement analysis purposes. Communication spectrum graph show the actual measurements of the network traffic. [15]

E. PLC for large-scale control and automation systems

As we know that for communication purposes PLC uses the existing power line infrastructure for data communication. So the PLC has been discussed for multimedia communication as well as broadband access. But the approach of PLC is not just limited to high speed internet access and data sharing but modern era is taking it to a whole new level such as energy management systems, automation systems, control as well as sensing. For using the existing infrastructure there are several transmission concepts. For the wired and wireless communication telecommunication companies are now heading towards PLC. Early in this century PLC-based networks such as PLC-based LANs was considered the recent development in terms of standardization. Major advantage of using the PLC is to use the existing power line infrastructure for communication purpose. Energy management in advance is considered as the prior research approach for PLC for example the new technology that is Real time energy management technology with the use of power lines and internet [16].

F. Location Assisted routing techniques for PLC in smart grids

Major role of PLC is to provide several ways to reduce the shortcomings of the electricity grids and to provide facilities so that the entire world would be the electricity dependent world. So many elements of grid are linked for this purpose all of the separate elements of grid are utilized to work together as a unit. Grid will provide control and designed environment in such a way that low and medium voltage will be managed and characterized for node connectivity. By using stationary nodes the problem that is needed to be addressed is unicast messages. For this purpose performance regarding transmission delay and energy consumption is motivated and investigated in this paper [17].

G. Neighborhood-Knowledge based geo-routing in PLC

For future smart grids PLC technology is the strong applicant towards communication by using electricity as a mean. Communication between the smart grid electricity voltage span and the PLC devices is not easily achievable due to high signal collision and distortion. To ensure the data transmission and connectivity there is an essential need of multi hop routing. Multi hop routing uses the information of PLC devices location that is known the idea of geographic routing. The newly proposed algorithm idea of making knowledge based regarding the neighbors which involves immediate connectivity in the neighborhood, so the knowledge based will be updated and the multi hop transmission using the geo-routing. In recent years researcher have been working on the compatibilities of smart grid applications to build new transmission technology by using advanced metering and introducing the integration of the energy generators to the advanced technology. PLC in this context has gain priority in academic as well as in the research areas. PLC technology is heading towards the enabling smart grid technology [18].

H. Opportunistic Routing for Wireless Networks

Performance of wireless and ad hoc networks can surely be improves by the use of opportunistic routing. In very consistent and localized manner the collaboration intermediate nodes is utilized for packet forwarding in opportunistic routing. By taking in account the broadcast facility of wireless networks the opportunistic routing helps in network throughput a well as the reliability of data transmission. Routing basically involves in route selection from routing table maintained by the router and then packet forwarding. Route selection involves selection of one or more routes by connecting two or more nodes. Whereas packet forwarding provides selection of best route by selecting any neighbor to send data to particular destination. Wireless networks has location changing and dynamic in nature this characteristics of wireless network makes routing as a challenging job in wireless networks [19].

III. DHT-Based Routing in PLC

DHT provides a scalable and combined policy for handling application data. It provides LID-based (Logical Identifier-Based) indirect routing and location framework. Furthermore, it provides a simple API (Application Programming Interface) for designing a routing protocol that can be used for a various types of applications. Following are the important term and their definitions to understand different concepts associated with DHT-based routing [20].

Functions of DHT are network establishment (addressing), secondly route discovery (lookup) and thirdly routing. When a node joins a network it tries to get information of its physical neighbors that is all other nodes those are in direct frequency range. Each node periodically broadcast hello messages to its physical neighbors in the network [21].

IV. DHT-Based Routing Protocols

DHT routing protocols are much efficient than the traditional protocols and following are the notable DHT protocols.

A. Dynamic Access Routing Protocol (DART)

DART is an efficient routing protocol, DART is similar to the other modern protocols such as Tribe. DART routing protocol works with the address of the node in such a way that it breaks the address into two parts for the identification of the location of node, these two parts are called static and dynamic part. DART routing protocols perform three important function in to the network one is to allocate a network address to the node. Second is to transmit data packet from one location to another at required destination. Third function is to map each node identifier this function is called node lookup, this lookup is called distributed lookup [23].

B. Virtual Ring Routing (VRR)

VRR stands for Virtual Ring Routing, VRR routing holds a hierarchy that is independent on the basis of location, and eliminates the causes of flooding. VRR can work with the distributed hash table routing scheme effectively. Routing in VRR is independent on the basis of location that is the major reason it does not cause flooding. Nodes creates a virtual ring by the order of location identifier. The node identifiers uses the integer number to indicate the location of node itself. Same as DART the nodes in VRR holds the routing table which holds the information regarding the network address of the neighbors that resides in the virtual ring. Each neighbor have the pair of entry into its routing table regarding its own neighbor and broadcast it to the adjacent neighbors [25].

C. VCP

VCP protocol is the advanced newly proposed protocol. VCP stands for Virtual Cord Protocol. The VCP take account of the conventions of the DHT routing protocol and uses the functions those were used in DHT based routing. As it follows the routing mechanism of the distributed hash table VCP is considered more applicable. In VCP the information regarding the location is not included as routing information. And each node has its own logical address that is called LID or logical identifier [26].

D. PROSE

PROSE routing protocol have the simple approach in obtaining the routing information. The two major nodes play their role one is root node and second is AN-node that is also called anchor node. The routing table has the information of the prefix address of the targeted node to whom sender want to access. The address labeling in this sort of routing uses the prefix of the network identifier related to sender and the prefix of the network identifier related to the receiver and combining this package it makes a hello message and sends on the network. Due to follow the prefix technique this type of routing follows multiple paths approach as several paths could have the same prefix as the receiver has. Source node requests the anchor node through the use of distributed hash table [27].

E. 3-DRP

Another routing scheme that provides the solution to the mismatch problem. 3-DRP uses the DHT based technique. This techniques uses both physical and logical topology to perform the routing. The logical location and physical location of nodes both are adjacent in this technique. If two nodes are physically closer to each other than both should be closer with respect to their logical location. The logical identifier structure is used in this technique. The adjacency of logical and physical location as well as the use of LIS avoids the mismatch problem [28].

V. Problem Statements

The problems statements of the study are as under:

a) Electrical vehicle communication through PLC is the upcoming idea for this work. When two electrical vehicle move towards different directions and when vehicles attach to smart grid for charging so their location is changing from direction to direction. When location changes it is not static so we are unable to compute geographic coordinates through map.

b) Ad hoc On Demand Distance Vector (AODV) routing protocol for PLC. AODV based protocol for smart grid and PLC causes flooding, in which route location must be examined to obtain LIDs. But after assigning LIDs to nodes the flooding problem caused by AODV based protocol can be avoided [29].

c) Let's consider the illustrated map in figure 8 coordinated with physical nodes. Once data is transmitted from source every packet receiving node calculates its distance from the destination, the node with shortest distance from destination will expire its timer earlier. Let's suppose one node is at physical location 723 in the figure and wants to send data to geographic node with physical id 718. Transmitted data will be received by node 702, 701 and node 730. But the problem with transmission is that data will not be received by the destination node because nodes 702, 701 and node 730 are not near to the destination, and they will not retransmit the received packet. Every location based routing such as GPRS also causes this problem. This problem is solved by Peremiter Mode. But if we use LIDs instead of physical IDs then this problem can be avoided [13].

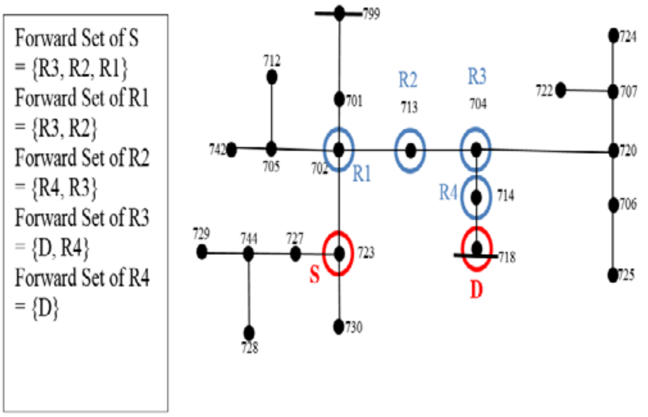

Fig. 4 An example of a path in IEEE 37 Node Test Feeder

Let's consider the illustrated map coordinated in figure 8 with physical nodes. Once data is transmitted from source every packet receiving node calculate its distance from the destination, the node with shortest distance from destination will expire its timer earlier. Let's suppose one node is at physical location 723 in the figure and wants to send data to geographic node with physical id 718. Once data is transmitted from source every packet receiving node calculate its distance from the destination, the node with shortest distance from destination will expire its timer earlier.

Let's suppose the (x, y) coordinates of 723, 701 and 718 are (4, 3), (4, 9) and (7, 3) respectively.

By using Euclidean distance between two points.

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

Distance between 723 and 701 is 6, and distance between node 723 to 718 is 3, which is smaller distance in terms of location. Hence we know that the source node 723 is physically far from destination node 718. But location wise 723 and 718 are near.

A. Proposed Solution

To transmit data depending on location we use LIDs. Let's suppose we have LID Logical Space [0-10]. LID is assigned on the basis of neighbors in order to avoid mismatch. LID would be assigned based on neighbors. Assigned LIDs are as under:

Table I: Assigning LIDs

Node: Logical Space	Assigned LID
723: 0-1	0
702: 1-2	1
713: 2-3	2
704: 3-4	3
714: 4-5	4
718: 5-6	5

Figure below shows the source to destination transmission after assigning LIDs. As shown in figure we have 5 nodes with UIDs (723, 702, 713, 704, 714 and 718) in the physical network. The LIDs of 723, 702, 713, 704, 714 and 718 are 0, 1, 2, 3, 4 and 5 respectively.

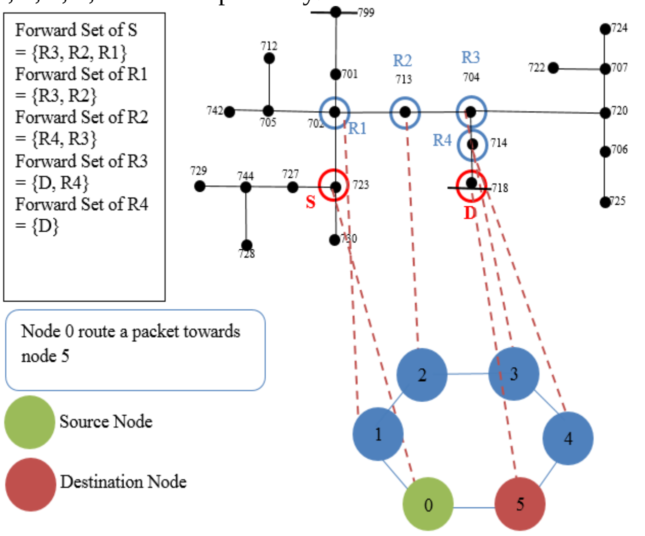

Fig. 5 Using LIDs for path in IEEE 37 Node Test Feeder.

Lookup Service or route discovery routing is performed based on LIDs in the network as follows: If a node say “723” with LID=0 want to send data to node “714” with LID=4 then node “723” will apply hash function over the node’s UID in order to get the LID of node “714”. After getting the LID of node “714” that is LID=4. Node “723” will follow the query to its neighbors in its logical network to one of its neighbors in logical network which has closest LID to the destination node is LID. In this particular case (who is closest?)

5-4 = 1 (Closest)

4-1 = 3

In this case node “723” will forward to node “718” with LID=5, this continues on each receiving node till the reach to its destination. So in this case therefore one can see that in a DHT based routing eliminate network wide flooding.

Second case let’s consider when “723” sends data to “718” that is when 0 sends data to 5 As shown in Figure below through arrows. After receiving the data node “718” will forward to node “714” with LID=4 which is the final destination as shown in figure below.

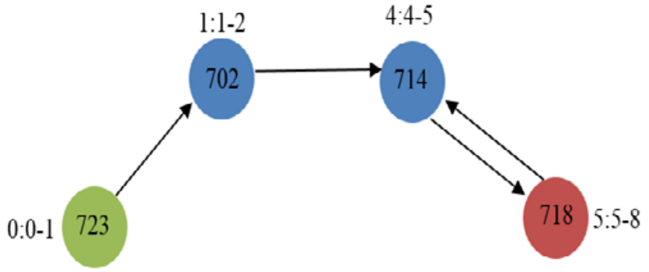

Fig. 6 Communication after receiving mapping information

B. *Merits of Assigning Logical IDs*

Firstly LIDs will support the movable nodes that are electrical vehicles in our particular case. Secondly for static nodes we will not take geographical coordinates through map but through LIDs. When electrical vehicle attach to one place then its IP address will be placed to anchor node, then node’s LID will also be placed on anchor node then communication will be start, disadvantage of this proposed scheme is the involvement of end to end delay. Because first LID will be required from anchor node then it enables further communication procedure [53].

VI. Proposed Work

This section discusses about the relationship between the problem statement and proposed solution in detail.

Major problem with DHT was that the logical and physical neighbors are mismatched. By using the example of VCP routing protocol we would avoid mismatch. Let’s suppose we have LID Logical Space [0-1]. LID is assigned on the basis of neighbors in order to avoid mismatch. LID would be assigned based on neighbors. VCP assigned LS space is [0 to 1]. Let’s Suppose LS Space is [0 to 1], where value 0 is the lower end and value 1 is the upper end. In cord every node have two neighbors those are successor and predecessor. Major improvement in VCP as compare to cord is that Lower LID has no predecessor and upper LID has no successor [24].

A. *VCP Implementation*

Major problem with DHT was that the logical and physical neighbors are mismatched. By using the example of VCP routing protocol we would avoid mismatch. Let’s suppose we have LID Logical Space [0-1]. LID is assigned on the basis of neighbors in order to avoid mismatch. LID would be assigned based on neighbors. VCP assigned LS space is [0 to 1]. Let’s Suppose LS Space is [0 to 1], where value 0 is the lower end and value 1 is the upper end. In cord every node have two neighbors those are successor and predecessor. Major improvement in VCP as compare to cord is that Lower LID has no predecessor and upper LID has no successor. VCP Steps to improve cord structure are as follows: Note that LID is assigned on the basis of neighbors.

Step 1: First node is arrived, it will get LID “0”, and then node 0 will wait to hear any hello message. If it does not receive hello message then it is the first one. First node takes the whole space from 0 to 1. Node “0” has no successor and no predecessor.

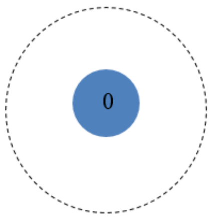

Fig. 7 VCP Step One

Step 2: Next node is arrived, it will wait before joining for a specific time, after receiving hello message this new arrived node will get LID according to the existing node. Node “0” tells the new arrived that it is the first existing node. Then it assigned “1” as LID to new node. Successor of node “0” is node “1”. Node “1” has predecessor node “0” but node “1” do not have successor. Note that node “0” has no predecessor.

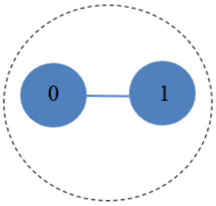

Fig. 8 VCP Step Two

Step 3: Third node is arrived, it receives hello message from "0" and from "1" both. Then new node considers that both node "0" and node "1" are my neighbors. As we know that node "0" and node "1" are both logical neighbors to each other. Then third nodes will get LID in center of node "0" and node "1".

(0+1)/2=0.5

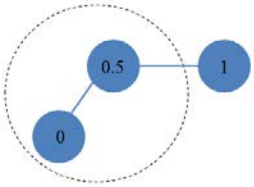

Fig. 9 VCP Step Three

Now successor of node "0" is node "0.5" and "0" do not have predecessor. Predecessor of node "1" is node "0.5". And node "1" do not have successor.

Step 4: Fourth node is arrived it will receive information from node "0.5" and from node "1" and both node "0.5" and node "1" are logical neighbors to each other.

(0.5+1)/2=0.75

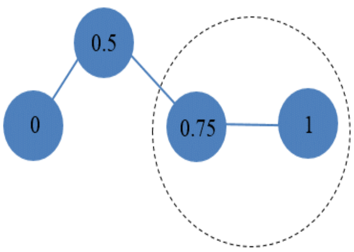

Fig. 10 VCP Step Four

Step 5: Fifth node is arrived it will receive information from node "0.5" and from node "0.75" and both node "0.5" and node "0.75" are logical neighbors to each other. And node "0.5" and node "0.75" must be logical and physical neighbors to each other.

(0.75+0.5)/2= 0.6

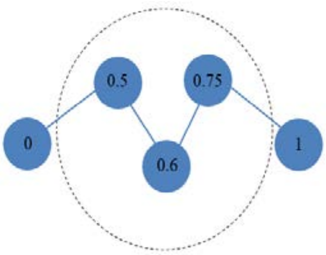

Fig. 11 VCP Step Five

Step 6: Sixth node is arrived it will receive information from node "0.5" and requires from node "0.5" to create a virtual neighbor node that is node "0.6" now both node "0.5" and node "0.6" are <u>virtual neighbors</u> to each other.

Calculating virtual neighbor (0.5 (physical) + 0.6 (virtual))/2= 0.55 (virtual)

Calculating LID of new arrived node (0.55 (virtual) +0.5 (physical))/2= 0.52

Now the new node "0.52" have successor node "0.55" which is virtual node and predecessor node "0.5" which is physical node.

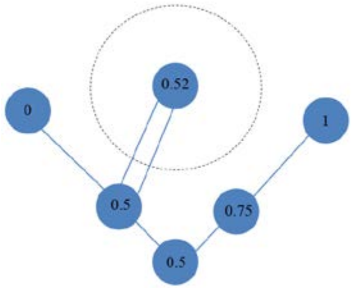

Fig. 12 VCP Step Six

Let's suppose node "0" wants to send data to node "0.75". Question is that how node "0" will get the LID of node "0.75"? In previous case the LID was based on UID then LID of destination can be obtained by applying hash function on UID. But here LID is assigned on the basis of neighbors.

Node "0.75" will apply hash function on its own IP address. Answered value of hash function will be in between "0" and "1". Let's suppose answer after applying hash function is "0.2". Value "0.2" is closest to "0.6"

| 0.6 (destination) -0.2 (LID) |=0.4

| 0.6 (destination) – 1 (LID) |=8

Now value "0.4" is closest, so it will give packet to node "0.6" which is anchor node. To find this anchor node next calculation is as follows:

| 0.6 (source) -0.2 (LID) |=0.4

| 1 (neighbor) – 0.2 (LID) |=8

| 0.75 (neighbor) -0.2 (LID) |=0.55

Now value "0.4" is closest, so it will give packet to node "0.6" which is anchor node. To find this anchor node next calculation is as follows:

| 0.6 (source) -0.2 (LID) |=0.4

| 0.75 (neighbor) – 0.2 (LID) |= 0.55

| 0.5 (neighbor) -0.2 (LID) |= 0.3

Now value "0.3" is lowest, so it will pass packet to node "0.5" which is anchor node. To find this anchor node next calculation is as follows:

| 0.5 (source) - 0.2 (LID) |= 0.3

| 0.52 (neighbor) – 0.2 (LID) |= 0.32

| 0.6 (neighbor) - 0.2 (LID) |= 0.4

| 0 (neighbor) – 0.2 (LID) |= 0.2

Now value "0.2" is lowest, so it will pass packet to node "0" which is anchor node. To find this anchor node next calculation is as follows:

| 0 (source) - 0.2 (LID) |=0.2

| 0.5 (neighbor) – 0.2 (LID) |= 0.3

Now again value "0.2" is lowest, so node "0.2" says I am responsible for sending this packet. I am the closest. Then it keeps the packet on node "0". Node "0" is now the actual anchor node of destination node "0.75". Logical ID of node "0.75" will be stored on node "0".

Anchor Node: Let's suppose node "0.52" wants to send data to node "0.75" that is called node A. Now node "0.52" will apply hash function on the IP address of node "0.75" which will answer in value "0.2" and using "0.75" as destination address and by following the above procedure it comes to node "0". Because logical ID of node "0.75" which is "0.75" that is stored on node "0".

Note: Anchor node stores the LID if nodes. Every node apply hash function on its own IP address which will result in the range of 0 and 1. And by following the above procedure packet will get to destination [24, 30].

B. Flooding Elimination via DHT Routing Protocol

Routing when any node wants to transmit data to another node that is destination node. Source node has to be aware of the route. By applying hash function on LID source node finds out the route. The mapping information regarding destination node is then sent to source node as a request query. Then destination replies with LID and LSP that is the mapping information of destination node [22].

After receiving information from destination, now sender is able to communicate with receiver. Then the sender node passes that data packet to neighbor next to it. That neighbor have closest LID towards the destination LID that recorded in packet. This process continues until the packet gets to destination. Following figure presents route from node 0 to node 5 by using LSP and LID mentioned in figure.

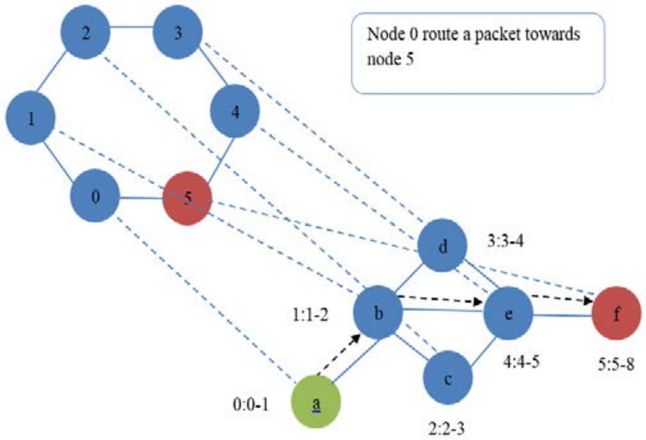

Fig. 13 DHT Based Routing

Disadvantage Logical neighbor of "5" is "0" are assigned randomly, but physically it is far away which causes duplicate or redundant data transmission. It is called mismatch problem. Because LID is assigned on the basis of UID. One can see that this routing is not an efficient one because node "a" with LID=0, but node "f" with LID=5 is physically far away because logical and physical neighbors are not adjacent. To resolve this issue VCP scheme is proposed which utilizes the hello messages from its physical neighbors [22].

VII. IMPLEMENTATION AND SIMULATION

For the implementation and simulation purposes there are several environments are available but network simulator is feasible and Linux operating system Fedora 24 updated. Module PLC is open source and available at github repository. Python and c++ programming environments are used to implement the topology that is proposed in this study.

A. Simulation Environment

For the detailed simulation of the proposed network NS-3.25 simulator is used for the simulation and analysis purposes on both of the network layers.

B. Quality of Routing Paths

The stretch ratio can be used to computer the quality of the routing paths and the network efficiency due to the computation of the shortest path and the traverse length comparison. The smart grid network of power line communication here is made in a ring like structure. The stretch value computed through the routing path stays below 25% as the network is deployed without the virtual cord protocol that takes logical identifiers to identify the nodes on the network. VCP provides us the logical identifiers for the nodes which gives the low stretch ratio as shown above and the protocol VRR increases the stretch level to 40% with one forty nodes on the network.

C. Network Size Influence on protocol

Network size influence can be analyzed through the several packet transmissions on the network using the virtual cord protocol. For this purpose the nodes that were used in the network are 10, 20, 30 and 40 nodes to compare the results are have in-depth analysis of the newly deployed network. The packet size and the time interval was not changed to only see the influence of the network size so that the other attributed are not confused with the network size. The VCP takes approximately fifteen seconds to take the packet to the estimation on 50 nodes network while other flooding protocols could take approximately 100 seconds to reach the protocol to its destination. If we increase the nodes in the network up to 100 then virtual cord protocol takes up to 30 seconds to decide path towards destination and reach for the packet. While other flooding nodes increase the time up to 147 at hundred nodes.

D. Load Influence on results of protocol

The traffic load is an important attribute to check the performance efficiency of the network the nodes on topology are forty and the hundred packets traffic are sent from the sender node to receiver node. Time interval was set to [0-1] seconds and on forty nodes network we send two packets in the provided time interval. Basically the delay of the time in packet receiving increases when the traffic load in increased. Actual perceived time of the packet transmission is 500 packets per seconds. With this rate the packet congestion id totally neglect able or in a minute number of range. If we reduce the time interval from range [0-0.5] and the packet rate is still the same that is 400 packets per second then again we can observe that we sent 20 packets very easily without the congestion.

E. Comparison to Standard Routing Technique

The performance of the virtual cord protocol in the proposed topology of the power line communication. The protocol can be compared to the existing flooding protocol in the range. If we compare the attributes the flooding protocols such as OLSR, DSDV, AODV, DSR and the VCP protocol these are same up to some extent.

F. Simulation Scenario

For the purpose of the comparison of the VCP, the protocols those provides flooding are most common to compare the results with. Because these flooding protocols are easy to implement and require reasonable system requirements as well as simple in designs.

- Nodes of the network deployed could be arranged in a ring or rectangle shape or could place in a grid like environment.
- For a long rout communication the network cluster head should be connected to the gateway and the 1 hop average distance is required. For this purpose field size is controlled.
- The node 1 is selected randomly, the network sink packet was identified globally.
- For the burst communication random pattern is used for the exponential transmission. An extra packet is sent at time value 10 seconds.

Total transmission of packets and the possibility of the collision that id collision rate is measured through the proposed network. The collision rate also take account of the congestion.

G. Collision on MAC Layer

Taking account of the MAC layer the researcher checked the number of transmission and the number of collisions on the proposed network. For a network consisting 10 nodes the number of collision could increase up to 9 because of single head in the cluster of the nodes. If we increase the number of nodes the collision could also increase unless or until we use VCP by using VCP the number of collisions could avoid and reduced down as compare to the flooding protocols.

For the network of 40 nodes number of collision could be computed as 39×39=1521. While in newly proposed technique collision cloud be reduced to 81+81+81+81=324. Similarly if we increase the number of nodes in the network then number of collision could be 81 per 10 nodes, it can be added respectively. While for the flooding protocol the collision is computed as above that is 1521. Similarly for 50 nodes it could be 81+81+81+81+81=405 and 49×49=2401.

Table II: Collision at MAC layer

Protocol	No. of Nodes	Packets	Collisions
Flooding	30	100	84100
	40		152100
	50		240500
VCP	30	100	24300
	40		32400
	50		40500

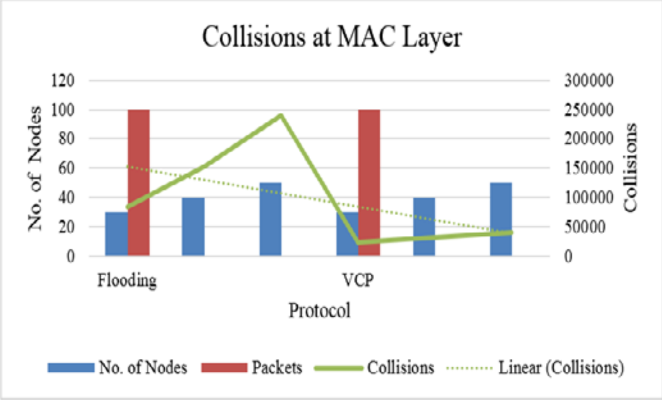

Fig. 14 Collision at MAC Layer on Network Nodes.

H. Total Transmission with in the Network

Total transmission is another essential attribute to measure the performance of a network, total transmission also indicates the efficiency of the network. The throughput of the network can be computed through the total transmission of packets on the network. The performance of the network can be seen through the transmission held on network. In the topology proposed in this study transmissions hundred seconds, the interval could be set to three seconds then total transmission results would be 15, 21 and 27 in case of our proposed virtual cord protocol. And for the routing protocols those hold flooding 87, 117 and 147 that is notable difference.

Table III: Total Transmissions within the network:

Protocol	No. of Nodes	Hello Message Time	Transmissions
Flooding	30	3 Sec	87
	40		117
	50		147
VCP	30	3 Sec	15
	40		21
	50		27

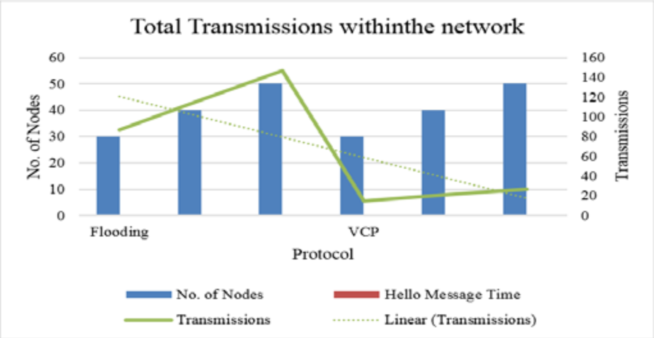

Fig. 15 Results on Network Nodes

I. Delivery Ratio:

Delivery ratio is presented as follows.

Table IV: Delivery Ratio within the network:

Protocol	No. of Nodes	Packets	Delivered	Delivery Ratio
Flooding	30	1000	324	92.57143
	40		431	61.57143
	50		768	73.14286
VCP	30	1000	337	96.28571
	40		558	79.71429
	50		842	80.19048

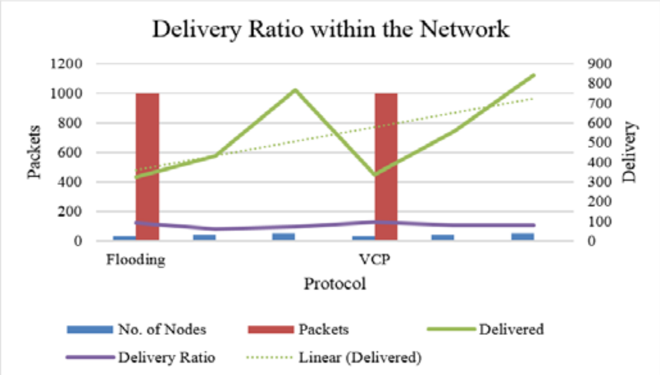

Fig. 16 Delivery Ratio within the Network

J. Number of MAC Transmissions:

Number of MAC transmissions are presented as follows. Table 5 presents the total MAC transmissions.

Table V: Number of MAC Transmissions:

Protocol	No. of Nodes	Hello Message Time	MAC Transmission
Flooding	30	3 Sec	3010
	40		5342
	50		7565
VCP	30	3 Sec	3228
	40		6182
	50		8370

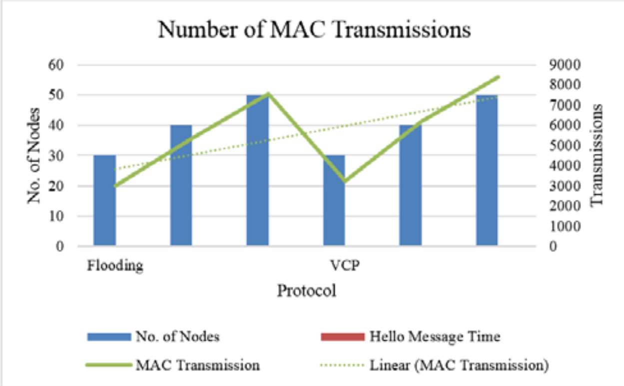

Fig. 17 MAC Transmissions within the Network

1.1.1. Average End-to-End-Delay:

Average end-to-end delay is presented as follows. Table below compares the performance of flooding base and proposed VCP based performance. Table shows the total and average delay.

Table VI: Average end-to-end delay within the network:

Protocol	Nodes	Packet Dropped	Total Delay	Average Delay
Flooding	30	26	101.54822	0.002901
	40	269	6.4477	0.009211
	50	282	9.933332	0.009460
VCP	30	13	101.06874	0.002887
	40	142	5.918434	0.008454
	50	208	8.975851	0.008548

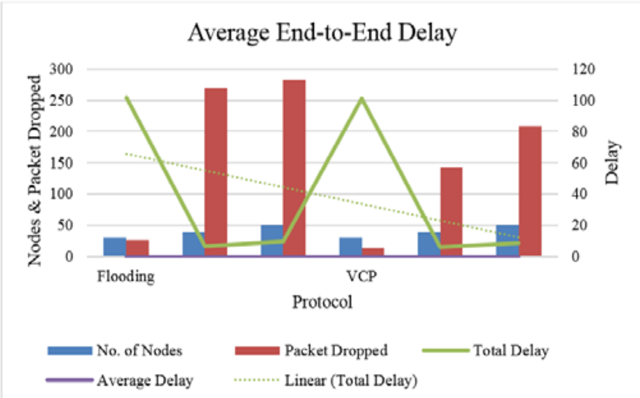

Fig. 18 Average End-to-End-Delay within the Network

VIII. Conclusions & Future Directions

A. Conclusions

The proposed technique in this study provides the following functionalities to the existing new network that is to be applicable where the network efficiency is needed:

a) This technique is used in the DHT protocol to improve the simplicity and efficiency of the network.

b) This technique is used in the virtual cord protocol and can also be modified to enhance the performance of the network.

c) This technique can be presented in the cluster shape network and provide the efficient transmission of packets up to one hop, where there are multiple clusters required there the it handle multiple hops transmission through the mentioned gateway of the network in efficient way.

d) The proposed technique also implement the idea of virtual cord protocol into the cluster of nodes and provide logical identifiers to the nodes, which allows the nodes and neighbor nodes to be aware of the length and structure of the network, which means the location of nodes where data is going to be sent.

e) The proposed technique depends on decentralization of network rather than centralization that is similar to the technique used in distributed hash table for merging detection.

f) This technique does not allow dead lock of packets to be occur, this allows the easy transmission of packets within the network across the nodes.

g) As compare to the protocols those provide flooding within the network, this technique is more suitable and transmission time efficient. Through this technique several number of nodes can be added to the network and yet efficient results could be achieved in the packet transmission.

B. *Future Directions*

As it is clear from the study [13], in OR, a source node obtains the destination node's geographic coordinates by using a map because nodes have fixed location in smart grid., In case nodes have mobility then map is not an efficient way to get the coordinated of destination node, For example, in case an electric vehicle. Logical IDs could be assigned through VCP (Virtual Cord Protocol). We will send packet on the basis of logical ID. Model of opportunistic routing can be implemented in VCP. If IDs are assigned logically then we do not need node mapping. For example if we use OR to send data to an electrical vehicle via PLC-based communication in smart grid, then in this case electrical vehicle changes its location of attachment to grid, so we must need to assign logical IDs. If one electrical vehicle send data to another then we need IDs assigned logically because vehicle changes its direction. And later more electrical vehicles would be attached to the network, then we would assign logical IDs to the nodes using VCP. After the electric vehicle is connected, it's the LID will be kept at a place as follows; Hash function will be applied to the `ID of electrical vehicle then the resultant value which is logical ID will be stored at particular place. Sender node will get the logical ID of receiver node, logical ID will tell whether node is attached to the network or not.

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