Routing Algorithm for a Clustered Network

Hemanth Kumar A.R, Sudhakara G and Satyanarayana B.S

***Abstract*—The Cluster Dimension of a network is defined as, which is the minimum cardinality of a subset S of the set of nodes having the property that for any two distinct nodes x and y, there exist the node s_1, s_2 (need not be distinct) in S such that $|d(x,s1) - d(y,s1)| \geq 1$ and $d(x,s_2) < d(x,s)$ for all $s \in S - \{s2\}$. In this paper, strictly non overlapping clusters are constructed. The concept of LandMarks for Unique Addressing and Clustering (LMUAC) routing scheme is developed. With the help of LMUAC routing scheme, It is shown that path length (upper bound)$PL_{N,d} < PL_D$, Maximum memory space requirement for the network$MS_{LMUAC(\Delta_i)} < MS_{LMUAC} < MS_{H3L} < MS_nc$ and Maximum Link utilization factor $ML_{LMUAC(i=j)} < ML_{LMUAC(i \neq j)} < ML_c < ML_{nc}$.**

***Index Terms*—Metric dimension, Cluster dimension, Cluster.**

I. INTRODUCTION

NUmerous routing protocols have been proposed in recent years. One of the most popular techniques for routing in communication networks is via distributed algorithms for finding shortest paths in weighted graphs [1],[2],[3],[4],[5],[6],[7]. These distributed algorithms differ in the way the routing tables at each host are constructed, maintained and updated. The primary attributes for any routing protocol are:

- Simplicity: Simple protocols are preferred for implementation in operational networks [8].
- Loop-free: At any moment, the paths implied from the routing tables of all hosts taken together should not have loops. Looping of data packets results in considerable overhead.
- Convergence characteristics: Time required to converge to new routes after a topology change should not be high. Quick convergence is possible by requiring the nodes to frequently broadcast the updates in the routing tables.
- Storage overhead: Memory overhead incurred due to the storage of the routing information should be low.
- Computational and transmission overhead: It is particularly important to limit these two in mobile wireless networks because the bandwidth of a wireless link is limited, and because mobile devices are typically low-power in order to be portable, and hence do not have the resources for many transmissions and lengthy computations.

Before to present the Hop ID routing algorithm, first describe the main motivations and put them in the proper context with the related works. Routing is a recursive procedure to forward packets ”closer” and ”closer” to the destination. The most critical component in any routing algorithm is how to measure the ”distance” between two nodes. This distance metric to a large degree determines the route performance, yet how to select this metric is non-trivial. Hop count or the shortest path distance is a natural candidate, since packets are forwarded on a hop-by-hop basis. But this poses considerable difficulty in ad hoc networks in that it incurs significant overhead to find and maintain the shortest path.

II. DEFINITION AND PARAMETER SETTINGS

A. Cluster Dimension

Definition .1. *The Cluster Dimension of a network which is defined, is the minimum cardinality of a subset S of the set of nodes having the property that for any two distinct nodes x and y, there exist the nodes s_1, s_2 (need not be distinct) in S such that $|d(x,s_1) - d(y,s_1)| \geq 1$ and $d(x.s_2) < d(x,s)$ for all $s \in S - \{s_2\}$. The elements of the set S are called the routers or route node or (resource locators) and the set S is called a* ***Cluster basis****. The Cluster dimension of a graph G is denoted by $\beta_c(G)$.*

B. Clustering

Definition .2.

1) *Let $G = (V,E)$ be a graph representing the given network. A clustering is a specific method of dividing the vertex set $V(G)$ according to the convenience of the user. For our purpose, the clusters are non intersecting non empty subsets of $V(G)$. Whose union is equal to $V(G)$.*
2) *The basic tool to introduce clusters in $V(G)$ is a ”metric” which is a shortest hop count distance between the nodes.*
3) *To every vertex, a unique clustering ID is generated which satisfies the properties of given in definition .1.*
4) *The j^{th} cluster, say C_j contains vertex v_i, with ID $\left((Co-ordv_i)_1, (Co-ordv_i)_2, \ldots, (Co-ordv_i)_N\right)$, such that $(Co-ordv_i)_j < (Co-ordv_i)_k$ $\forall k \neq j$, $k = 1,2,3,\ldots,N$.*

To achieve an efficient path planning the following features are to be addressed and solved. The algorithms are developed and presented here to perform an efficient path planning.

- Path planning from Member node to CH of Source.[FORWARDING]
- Switching between CHs at level 1 (w.r.t Source and Destination Hop ID).[SWITCHING]
- Path planning from CH of Destination to Destination node.[ROUTE DISCOVERY]

The above addressed algorithm explores the following features

- Multihop Network

Hemanth Kumar A.R is with the Department of Electronics and Communication, Manipal Institute of Technology, Manipal, Karnataka State, 576104, INDIA.: see http://hkr_mit_research@yahoo.com

Sudhakara G is with the Department of Mathematics, Manipal Institute of Technology, Manipal, Karnataka State, 576104, INDIA.: see http://sudhakaraadiga@yahoo.co.in

Satyanarayana B.S, Principal, R V College of Engineering, Bangalore, INDIA.: see http:// satyang1@yahoo.com

- Distributed Routing Algorithm
- It is on demand routing protocol
- It helps in tracing the path from source to destination more effectively through cluster heads (wireless)

The purpose of designing and developing the routing algorithm is to effectively path planning from source to destination.

C. Parameters:

- R_{Start} is a parameter which tells the distance from the cluster head and beyond which the nodes in cluster should receive and forward the data packets keeping a copy with them. i.e, $R_{Start} = d$ means only those nodes which are either at or beyond the distance d from the cluster head should receive and forward the packets keeping a copy. This parameter is set at the cluster head of each cluster.
- R_{Stop} is a parameter which tells the distance beyond which no node should receive the packets. All received nodes will keep a copy and forward.
- F is a parameter which stores an integer value say d and tells that nodes should receive and forward packets is done with out keeping a copy by every node at distance less than d.
- PW - Path weight is a parameter which stores an integer value which is initially zero at every member node. Once the destination node u_d is identified, assign a non zero integer called k, path weight, to u_d. (which is at distance d from the cluster head). Then find a node say $u_d - 1$ with j^{th} Co-ord value $(d-1)$ in the neighbor table of u_d. Assign the path weight k to $u_d - 1$. Continue this procedure till we reach u_0 which is the cluster head. In this procedure, at any stage, the tie are broken at random.
- D is the parameter which can have value either 0 or 1. If $D = 0$, then single cluster head communication. If $D = 1$, then distribute to all the cluster heads.
- $Neighbor - Table$: This table is a matrix which is associated with the vertex v belonging to cluster C_j. Neighbor table list is a $2(K+1)$ array where K is degree of v in G. In every row, in the 1^{st} column the unique clustering Hop Id of the corresponding vertex is stored and in the 2^{nd} column the j^{th} Co-ord of that vertex is stored. In the 1^{st} row 1^{st} column source ID is stored and 1^{st} row 2^{nd} column the j^{th} Co-ord of vertex v is stored. In the remaining K rows ID of the neighboring vertices and then j^{th} Co-ord are stored as follows. From top to bottom, those nodes having the j^{th} Co-ord same as that of v are stored in the beginning, those having j^{th} Co-ord one less than that of v are stored next and finally, those having j^{th} Co-ord one more than that of v are stored.

Assumptions:

- A node is aware of all its neighbors at all times
- All packets transmitted over a link are received correctly and in proper sequence within a finite time
- All control message are processed one at a time at the nodes in the order in which they occur.
- Communication between cluster heads is wireless(which is an additional cost)

TABLE I
NEIGHBOR TABLE

Source ID of v	j^{th} Co-ord of Source
Neighbor ID of v	same as j^{th} Co-ord of Source
$\vdots$	$\vdots$
Neighbor ID of v	j^{th} Co-ord of Source-1
$\vdots$	$\vdots$
Neighbor ID of v	j^{th} Co-ord of Source+1

III. LMUAC ROUTING SCHEMES

Let G be a graph and $G = (V, E)$ and let $u, v \in V$. Let u be a source and v be a destination in vertex set V of a network. Let u be a vertex in a cluster C_j, $u \in C_j$ which is a member node having j^{th} Co-ord non zero. The **L**and**M**arks for **U**nique **A**ddressing and **C**lustering algorithm(LMUAC) which is developed for path planning from source vertex u to destination vertex v consists of three phases a) Forwarding , b) Switching and c) Route discovery. First and foremost in a network by using LMUAC Algorithm unique ID is generated for clustering and assigned to each and every node. clustering Algorithm is executed to form non overlapping clusters and the nodes are identified as a member node, cluster head and gateway node these execution are carried out during off line conditions. The resultant is each and every node is now associated with unique clustering ID. Now our aim is to path planning from source u to destination v . The first phase of the LMUAC algorithm is **forwarding** data packets from source u to the cluster head of that cluster C_j . The second phase is **Switching** if the source and destination nodes are in different clusters through the cluster heads. The third and final phase of LMUAC routing is **route discovery** from CH to destination node either it may be in a same cluster or in different cluster. each phase of the LMUAC routing is explained in detail.

A. FORWARDING

Let u be a vertex in C_j and if it is a source initiated then the data packets which is associated with the destination ID is forwarded from the source to the cluster head through intermediated nodes if the j^{th} Co-ord of the vertex $u > 1$. The source will verify from the neighbor table of u and check for the neighbor having the j^{th} Co-ord $\leftarrow$ (jth Co-ord of u-1) and forward to that member node . The ties are broken in random. This procedure will continue until the (j^{th} Co-ord y)=0 , $y \in C_j$. If the j^{th} Co-ord of y=0 , then y is a cluster head. Stop forwarding the data packets associated with the destination ID once it has reached the cluster head this process is known as forwarding. which is as shown in the below figures The algorithm is developed to forward the data packets from source to cluster head.

From the below figure a source is a member node say u initiated which is at hop distance 2 hop from the cluster head C_j . The j^{th} Co-ord of the source initiated is 2 which is not a cluster head, it will see its neighbor table and select a neighbor member node which is having the j^{th} Co-ord lesser than the source. There exist two member nodes having the

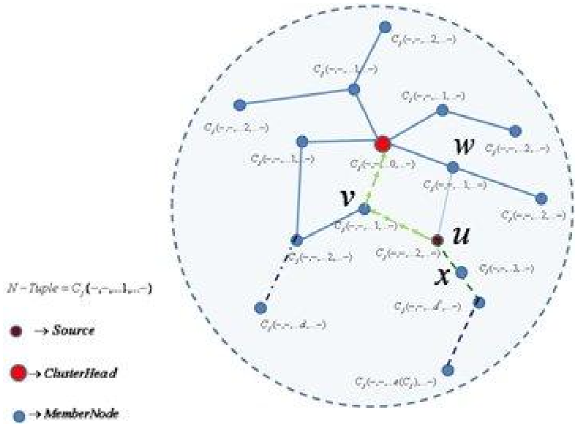

Fig. 1. Forwarding

TABLE II
NEIGHBOR TABLE OF A VERTEX u

Source u	2
v	1
w	1
x	3

j^{th} Co-ord lesser than one, so a tie exists. The tie is broken randomly and one of them is selected. Once the neighbor node is identified the data packets associated with the destination ID is forwarded for the selected neighbor. This process continues until the data packet reaches the cluster head. When it reaches the cluster head the process of moving the data packets is stopped. The first phase of the algorithm called forwarding is completed. In the end the data packets along with the destination Id is available at the cluster head of that cluster C_j.

B. SWITCHING

It is the second stage of LMUAC Algorithm to switch between cluster heads if both source and destination are in different clusters. The communication between the cluster heads are carried out based on whether there is a single destination or multiple destination which is discussed in the next sections.

1) Switching between Source Cluster Head to Destination Cluster head(Single Source and Single Destination): Once the data packets are available at the cluster head of that cluster C_j, then the process starts to identify the destination ID from the received data packets. The switching decision is to be carried are not, is decided by either Hierarchical code of cluster heads or the $posvalue$ of source and destination ID. If the $posvalue$ of destination is same as the value of cluster C_j then no switching is carried out. If it is different then switching is required from one cluster to another cluster. The major assumption is by considering the wireless communication between the cluster heads. We assume that if carry out the wireless communication then all the clusters with all the clusters should be in the desired communication range to receive the modulated data and demodulate the data at the receiving cluster head. The modulation is carried out by the source cluster head and demodulation by the destination cluster head. If the switching is to be carried out to all the clusters then the data is to be modulated by the general frequency where all the cluster heads are capable of demodulating the general frequency. The cluster head is also capable of modulating the data with all the pos value of cluster heads individually similarly demodulating them, this is a over head cost for constructing this LMUAC to work efficiently. If N clusters are their there must be frequencies available for cluster to cluster communication N frequencies for communicating for the individual cluster heads and one unique frequency for communication to all the cluster heads. The switching can be performed by two ways.

1)By Hierarchical code of Cluster Heads

Let $G(V, E)$ be a graph with n vertices and N clusters in a network. Let u be a source vertex then the $(co-ordN-Tupleu)_{N+1} = posval$. The pos val indicates the minimum value in the clustering unique ID.If $posval = j$, then the minimum value is in j^{th} position. If the minimum value is in j^{th} position then $u \in C_j$. The (co-ord N-Tuple $u)_j \neq 0, thenvertex\mathrm{u}isnotaclusterhead.Let\mathrm{v}beavertex\mathrm{v}\in C_j$. Where the $(co-ordN-Tuplev)_j = 0$, then v is a cluster head. A unique special code called hierarchical cluster head code is generated for the cluster heads to perform switching. The hierarchical code of the cluster head with respect to j^{th} cluster is, in its unique code it has a combination of exactly one zero and (N-1) 1s. it has zero in j^{th} position and 1s in remaining position. $HCH_j = \{1, 1, 1, \ldots, \underbrace{0}_{j^{th}-position}, \ldots, 1\}$

$(co-ordHCH_j)_j = 0$ and
$(co-ordHCH_j)_k = 1$, $j \neq k$,$1 \leq i \leq N$

Let x be a destination vertex $x \in C_k$ where $k \neq j$, then x is in different cluster the $(Co-ordN-Tuplex)_{N+1} = posval$. The $posval = k$, $j \neq k$ and $(Co-ordN-Tuplex)_k \neq 0$, then it is a member node of C_k . Let y be a cluster head of cluster C_k , then the $(Co-ordN-Tupley)_k = 0$. The hierarchical code for cluster head y is having zero in k^{th} position only and 1s in the remaining position. $HCH_k = \{1, 1, 1, \ldots, \underbrace{0}_{k^{th}-position}, \ldots, 1\}$

$(co-ordHCH_k)_k = 0$ and
and $(co-ordHCH_k)_i = 1$, $i \neq k$,$1 \leq i \leq N$

. If $u \in C_j$ and $y \in c_k$, then both source and destination are in different clusters . switching is to be performed from j^{th} cluster to k^{th} cluster , the modulation frequency is k from CH_j and demodulation frequency at $c-k$ is frequency k . To know from which cluster it has to switch . Consider the HCH_j and HCH_k hierarchical code and Xor them, check the values of 1s in the resultant. Switch from source to destination.

$$HCH_j = \{1, 1, 1, \ldots, \underbrace{0}_{j^{th}-position}, \ldots, 1\}$$

$$\otimes$$

$$HCH_k = \{1,1,1,\dots, \underbrace{0}_{k^{th}-position}, \dots, 1\}$$

The resultant is

$$= \{0,0,0,\dots, \underbrace{1}_{k^{th}-position}, \dots, \underbrace{1}_{j^{th}}, \dots, 0,0,0\}$$

Switch from j^{th} cluster to k^{th} cluster. The data packets along with the destination ID is switched from source to destination by using modulating frequency k , all the clusters are in the visible range.

2)By using source and destination pos value

Let $x \in C_j$ and $y \in C_k$, then the $posval$ of x is in the j^{th} position and the $posval$ of y is in k^{th} position then switch from source position to the destination position with modulating frequency (destination $posval$) and demodulating frequency at k^{th} cluster is (destination $posval$).

C. ROUTE DISCOVERY

The last stage of the LMUAC Routing algorithm. The decision of routing is decided by the applications which are discussed seperately in the next sections.

- Single Source and Multi destination in the cluster

1)Set parameters R_{Start}, R_{Stop} and F values

2) R_{Start} can have the values 0,d and $\acute{d}$

3) R_{Stop} can have values d, $e(C_j)$

4) F can have value ∞ or val

- Single source and Single Destination in the cluster

1) $F = val$, just forward upto that value only.

2) R_{Start} and $R_{Stop} = \infty$

3)For position based $F = val$ then compare the destination ID which is at val hops, if equal then receive.

4)Set TTL value for ACK based routing if destination is at d distance then set the value of $TTL = d$.

- Single source and single destination

Case (i) position based routing let x be a destination vertex in the cluster C_j which is at d hops from the cluster head CH_j . If single destination in the cluster C_j . The route discovery in the cluster C_j is as follows. To find an efficient route to the single destination from the cluster head three steps are to be carried out. They are as follows

1)Forward packet upto d hops destination. The vertex u which is at d distance from the cluster head is known. By setting the parameter value F the request is forwarded up to the member nodes which are at d hops far away from the cluster head. All the member nodes which are within d hops from the cluster head will forward the query along with the destination ID to the next member nodes which are having the $j^{th}Co-ord$ greater, this procedure is followed until it reaches d hop from the cluster head.

2)Find destination. The query available for all the member nodes which are at d hops from the cluster head of the cluster C_j . These query carry the destination ID along with the data packets. Once these data packets reach the d hops it compares the $N-T$uple of destination and if exist receive the data packets else stop.

3)Distribute data packet. Once the destination is identified which is at d hops from the cluster head the member nodes check the R_{stop} value which is d then the unique ID of each and every node which are at d hops will compare with nthe received Destination ID. If matching occurs then receive the data else discard the data packet.

IV. Results and Discussion

In this section this paper discuses the important comparative studies related to the Average path length, Maximum link utilization and Memory space requirement. In this paper it is shown that the parameters are to be chosen carefully for the best results to overcome the drawbacks. The next sections will discuss the general comparative studies for an upperbounds.

A. The upper bound for the average path length

If source and destinations are in different clusters then the communication will take place through the cluster heads. It is assumed that in LMUAC routing scheme the wireless communication takes place between cluster heads. Let u be the source cluster head and v be the destination cluster head, then from u to v switching will take place either by using the hierarchical or pos value switching. They are like fully connected (mesh)i.e, the cluster head will broad cast the data packet along with the destination ID, which is modulated by using pos value or hierarchical code. The hop count between cluster head to cluster head is atmost one hop through wireless communication.

Let D be the diameter of G with N clusters. Let $C_1, C_2, C_3, \dots, C_N$ be N clusters then let $n_1, n_2, n_3, \dots, n_N$ be the number of elements in $C_1, C_2, C_3, \dots, C_N$ respectively, then maximum diameter in the cluster be d_i, then $n_1-1, n_2-1, n_3-1, \dots, n_N-1$ is the maximum distance with $C_1, C_2, C_3, \dots, C_N$ respectively. Let x and y be the nodes in a network. Then

Case (i): Let x and y be two nodes in the network with x -a member node and y the cluster head in the same cluster C_j . Then the path length between x and y is atmost $(n_j - 1)$.

$$PL = (n_j - 1) \tag{1}$$

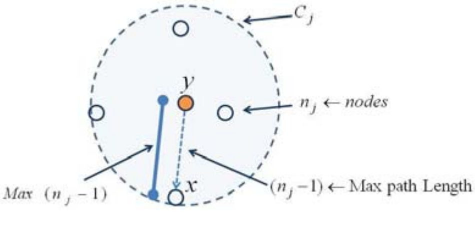

Fig. 2. x -a member node and y the cluster head

Case (ii): Let x and y be two nodes in the network with x a member node with cluster C_j and y a clusterhead with cluster C_k . Then the path length between x any y is at most $(n_j - 1) + 1$.

$$PL = (n_j - 1) + 1 \tag{2}$$

$$PL = n_j \tag{3}$$

Case (iii): Let x and y be two nodes in the network with x and y in the same cluster say C_j with n_j nodes. Then the path length between x any y , through the cluster heads, is at most $2(n_j - 1)$.

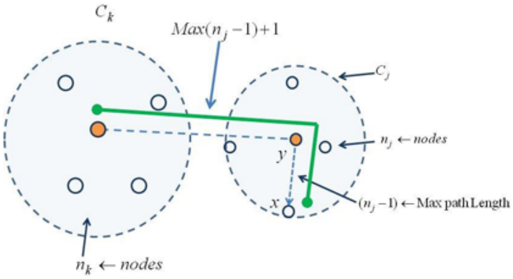

Fig. 3. x a member node $\in cluster$C$_j$ and y a clusterhead $\in$C$_k$

$$PL = 2(n_j - 1) \tag{4}$$

Case (iv): Let x and y be two member nodes in the cluster C_i and C_j respectively. Then the path length between x any y cannot exceed $((n_i - 1) + (n_j - 1) + 1)$.

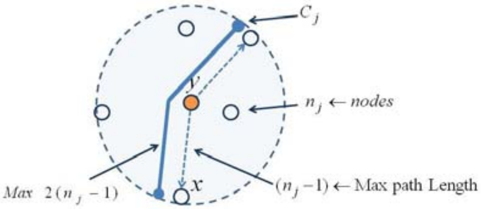

Fig. 4. x and y in the same cluster say C_j

$$PL = (n_i + n_j - 1) \tag{5}$$

In this it is to calculate the average distance one has to travel to move from any vertex to any other vertex in the clustered scenario. Where N is the total distance in a network

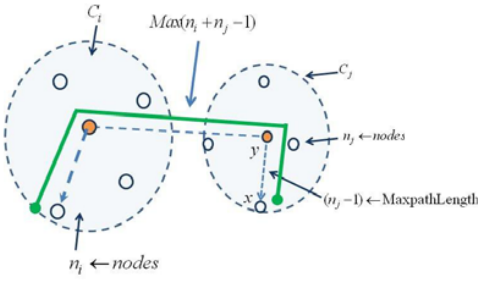

Fig. 5. x and y are member nodes in different clusters

N=$\sum_{i=1}^{k} C_2^{n_i-1} 2(n_i - 1) + \underbrace{\sum_{i=1}^{k}\sum_{j=1}^{k}(n_i-1)(n_j-1)(n_i+n_j-1)}_{i\neq j}$ (6)k is the distances between vertices, then k is given by

$$k = n(n-1) \tag{7}$$

Average path length (Upper Bound)= $\frac{N}{k}$

Example : Consider a network of n nodes in a network. Let D be the diameter of the graph G. Let N be the number of clusters in a graph G with diameter d. The average path length is calculated as follows by considering the below example. It is shown that $PL_{N,d} < PL_D$ should be chosen.
Let there be a network of 1000 nodes in a graph G,with diameter $D = 50$ of a network. The number of clusters in a network is 10 of various diameter varying from 40,35,30,25,20,15 and 10. It is to calculate the average path length by varying the number of clusters from 2 to 110 and compare the network performance with respect to N and d with D.
Average Pathlength for a given N and d in a clustered network= $PL_{N,d}$
Average Pathlength for a non clustered network $= PL_D$

$$PL_{N,d} = \frac{[(d-2)(d-1)N + ((d-1)^2(2d-1)(N-1)N)]}{n(n-1)} \tag{8}$$

$$PL_D = \frac{Dn(n-1)}{n(n-1)} = D \tag{9}$$

$$PL_{N,d} < PL_D \tag{10}$$

is always prefered for an average PL in an upperbound range. The below figures shows that this gives us a chance to make a proper choice of path length with respect to N, d. If the $PL_{N,d}$is $> PL_D$ then the average path length is increased. choose

$$PL_{N,d} < PL_D \tag{11}$$

B. Maximum Link Utilization(Upper Bound)

consider a network of n nodes in a network. Let D be the diameter of the graph G.Let N be the number of clusters in a graph G with diameter d_i and d_j. Let d_i be the maximum diameter of one of the cluster C_i and d_j be the next maximum diameter of one of the cluster C_j. The link utilization factor of the network is calculated as follows by considering the following examples.
Let there be a network of 1000 nodes in a graph G with diameter D of a network. The number of clusters in a network is 10 of various number of elements $n_1, n_2, n_3, \ldots, n_10$ .Calculate the average maximum link utilization with respect to non clustered, clustered and LMUAC Algorithm with respect to link utilization of the network, for the diameter $d_1, d_2, d_3, \ldots, d_10$ etc.
Max Link Utilization for non clustered Network(Flooding)= ML_{nc}

TABLE III
THE AVERAGE PATH LENGTH UPPER BOUND FOR 1000 NODES AND DIAMETER IS 50 AND CLUSTER DIAMETER VARIES 40,35,30,25,20,15,10 RESPECTIVELY

Clusters	PL_{N,d_1}	PL_{N,d_2}	PL_{N,d_3}	PL_{N,d_4}	PL_{N,d_5}	PL_{N,d_6}	PL_{N,d_7}
10	11.27	7.46	4.63	2.62	1.30	0.52	0.14
12	16.37	10.84	6.73	3.81	1.89	0.76	0.20
14	22.42	14.86	9.22	5.22	2.59	1.04	0.27
16	29.43	19.50	12.10	6.85	3.40	1.36	0.36
20	46.28	30.66	19.03	10.78	5.35	2.14	0.57
22	56.14	37.19	23.08	13.08	6.49	2.59	0.69
26	78.70	52.14	32.35	18.33	9.09	3.64	0.97
30	105.05	69.60	43.19	24.48	12.14	4.86	1.29
35	143.35	94.97	58.93	33.40	16.57	6.63	1.76
40	187.57	124.28	77.11	43.70	21.68	8.67	2.30
45	237.74	157.52	97.74	55.39	27.48	10.99	2.92
50	293.85	194.69	120.80	68.47	33.97	13.59	3.61
55	355.89	235.80	146.31	82.93	41.14	16.46	4.37
60	423.87	280.84	174.26	98.77	49.00	19.60	5.21
65	497.79	329.82	204.65	115.99	57.55	23.02	6.11
70	577.65	382.73	237.48	134.60	66.78	26.71	7.09
75	663.44	439.58	272.76	154.59	76.70	30.68	8.15
80	755.17	500.35	310.47	175.97	87.30	34.92	9.28
85	852.84	565.07	350.63	198.73	98.60	39.44	10.48
90	956.45	633.72	393.22	222.88	110.58	44.23	11.75
95	1065.99	706.30	438.26	248.40	123.24	49.30	13.09
100	1181.48	782.82	485.74	275.32	136.59	54.64	14.51
105	1302.90	863.27	535.66	303.61	150.63	60.26	16.01
110	1430.26	947.65	588.03	333.29	165.36	66.15	17.57
120	1702.79	1128.23	700.08	396.80	196.87	78.75	20.92
130	1999.07	1324.54	821.89	465.85	231.13	92.46	24.56

Max Link Utilization for Clusterd Network(Flooding within Clusters)= ML_C
Max Link Utilization for Clusterd Network with LMUAC Algorithm= ML_{LMUAC}

$$ML_{nc} = \frac{n(n-1)}{2} \tag{12}$$

$$ML_C = \left[\left(\frac{n_i(n_i-1)}{2}\right) * \left(\frac{n_j(n_j-1)}{2}\right) + 1\right]_i \tag{13}$$

$$ML_{LMUAC} = [(d_i - 1) + (d_j - 1) + 1]_{i \neq j} \tag{14}$$

$$ML_{LMUAC} = [2d_i - 2]_{i=j} \tag{15}$$

$$ML_{LMUAC(i=j)} < ML_{LMUAC(i \neq j)} < ML_c < ML_{nc} \tag{16}$$

C. Memory space requirement(Upper Bound)

consider a network of 3 level Hierarchy . Let a_i be the area in a graph G. let there be n_i nodes. let there be m such super areas and let there be k such super super areas with $a - i > m > k$. The total memory space required for each and every node of non hierarchical, hierarchical and LMUAC Clustered network.
Let there be a network of 1000 nodes in a graph G with diameter D of a network. The number of clusters in a network is 10 they are $a_1, a_2, a_3, \ldots, a_{10}$ of various diameter $d_1, d_2, d_3, \ldots, d_10$ and number of elements in each such areas are $n_1, n_2, n_3, \ldots, n_{10}$. In this paper it is now to calculate the maximum memory space required for the entire network with non hierarchical, hierarchical and LMUAC Clustered Network. Let there be 3level hierarchy in splits up as 50 nodes in a_i,$m = 20$ and $k = 3$.

Memory space requirement for non Hierarchical= MS_nc
Memory space requirement for Hierarchical Network with three level Hierarchy= MS_{H3L}
Memory space requirement for Clustered Network By LMUAC Algorithm= MS_{LMUAC}

$$MS_{nc} = n(n-1) \tag{17}$$

$$MS_{H3L} = \sum_{i=1}^{N} ((n_i - 1) + m + k)n_i \tag{18}$$

$$MS_{LMUAC} = \sum_{i=1}^{N} (2(k_i - 1)) + N \tag{19}$$

Let n be the total number of vertices in G. Let there be N Clusters $= \{C_1, C_2, C_3, \ldots, C_N\}$. The number of elements in $C_i = k_i$ in the worst case an element in C_i may be adjacent to $(K_i - 1)$ nodes , so maximum number of memory space at each vertex in $C_i = 2(k_i - 1) + 1$. In the real scenerio the maximum degree of a vertex is $< (k_i - 1)$.Let Δ_i be the maximum degree of a node in cluster C_i. Then the maximum memory space required for a $\Delta_i is$MS$_{LMUAC(\Delta_i)}$.

$$MS_{LMUAC(\Delta_i)} < MS_{LMUAC} < MS_{H3L} < MS_nc \tag{20}$$

V. CONCLUSION

The Cluster Dimension of a network is defined, which is the minimum cardinality of a subset S of the set of nodes having the property that for any two distinct nodes x and y, there exist the node s_1, s_2 (need not be distinct) in S such

TABLE IV
MAX LINK UTILIZATION FACTOR(UPPER BOUND)FOR 1000 NODES AND DIAMETER IS D

n	ML$_{nc}$	n$_i = \frac{n}{5}$	n$_j = \frac{n}{3}$	ML$_c(i \neq j)$	ML$_{Lmuac}(i \neq j)$	ML$_{Lmuaci}$	ML$_{Lmuacj}$
50	1225	10	17	5876	26	18	32
75	2775	15	25	31501	39	28	48
100	4950	20	33	102390	52	38	67
125	7750	25	42	254168	66	48	82
150	11175	30	50	532876	79	58	98
175	15225	35	58	994974	92	68	115
200	19900	40	67	1707335	106	78	132
225	25200	45	75	2747251	119	88	148
250	31125	50	83	4202432	132	98	165
275	37675	55	92	6171001	146	108	182
300	44850	60	100	8761501	159	118	199
325	52650	65	108	12092890	172	128	215
350	61075	70	117	16294543	186	138	232
375	70125	75	125	21506251	199	148	248
400	79800	80	133	27878224	212	158	265
450	101025	90	150	44755876	239	178	298
500	124750	100	167	68337501	266	198	332
550	150975	110	183	100199765	292	218	365
600	179700	120	200	142086001	319	238	398
650	210925	130	217	195906210	346	258	432
700	244650	140	233	263737057	372	278	465
800	319600	160	267	450570668	426	318	532
900	404550	180	300	722533501	479	358	598
1000	499500	200	333	1102238890	532	398	665

TABLE V
MEMORY SPACE REQUIREMENT(UPPER BOUND)FOR 1000 NODES AND DIAMETER IS D

n	MSc	n_i	Msl_{h3l}	$n_i/2$	$n_i/3$	$n_i/4$	$n_i/10$	MS(LMUAC)$\frac{ni}{2}$	MS(LMUAC)$\frac{ni}{3}$	MS(LMUAC)$\frac{ni}{4}$	MS(LMUAC)$\frac{ni}{10}$
50	2450	5	1350	3	2	1	1	200	117	75	0
75	5550	8	2213	4	3	2	1	488	300	206	38
100	9900	10	3200	5	3	3	1	900	566	400	100
125	15500	13	4313	6	4	3	1	1438	916	656	188
150	22350	15	5550	8	5	4	2	2100	1350	975	300
175	30450	18	6913	9	6	4	2	2888	1867	1357	438
200	39800	20	8400	10	7	5	2	3800	2467	1800	600
225	50400	23	10013	11	8	6	2	4838	3150	2307	788
250	62250	25	11750	13	8	6	3	6000	3917	2875	1000
275	75350	28	13613	14	9	7	3	7288	4767	3507	1238
300	89700	30	15600	15	10	8	3	8700	5700	4200	1500
325	105300	33	17713	16	11	8	3	10238	6717	4957	1788
350	122150	35	19950	18	12	9	4	11900	7817	5775	2100
400	159600	40	24800	20	13	10	4	15600	10267	7600	2800
500	249500	50	36000	25	17	13	5	24500	16167	12000	4500
600	359400	60	49200	30	20	15	6	35400	23400	17400	6600
700	489300	70	64400	35	23	18	7	48300	31967	23800	9100
800	639200	80	81600	40	27	20	8	63200	41867	31200	12000
900	809100	90	100800	45	30	23	9	80100	53100	39600	15300
1000	999000	100	122000	50	33	25	10	99000	65667	49000	19000

that $|d(x, s1) - d(y, s1)| \geq 1$ and $d(x, s_2) < d(x, s)$ for all $s \in S - \{s2\}$. In this paper, The overlapping clusters are constructed strictly. The concept of **L**and**M**arks for **U**nique **A**ddressing and **C**lustering (LMUAC) routing scheme is developed . With the help of LMUAC routing scheme ,It is shown that path length (upper bound)$PL_{N,d} < PL_D$,Maximum memory space requirement for the network$MS_{LMUAC(\Delta_i)} < MS_{LMUAC} < MS_{H3L} < MS_nc$ and Maximum Link utilization factor $ML_{LMUAC(i=j)} < ML_{LMUAC(i \neq j)} < ML_c < ML_{nc}$.

REFERENCES

[1]E. Gafni,D.P. Bertsekas, *Distributed Algorithms for generating loop-free Routes With frequently changing Topology*, IEEE Trans. On Communications, Vol. Com-29, no. 1, pp. 11-18, January, 1981.

[2]J. J. Garcia-Luna-Aceves, *A Unified Approach to Loop-Free Routing Algorithm Using Distance Vectors or Link States*, Proc.ACM Sigcomm Symposium on Communication,Architectures and Protocols, pp. 212-223, September, 1989.

[3]J. M. Jane,F. M. Moss, *A Responsive Routing Algorithm for Computer Networks*, IEEE Trans. On Communications, pp. 1758-1762, July, 1982.

[4]J. Mcquillan, *Adaptive Routing Algorithm for Distributed Computer Networks*, BBN Report 2331, BBN, Cambridge,MA, 1974.

[5]J. M. Mcquillan, I. Richer,E. C. Rosen, *The new Routing Algorithm for Arpanet*, IEEE Trans. On Communications,Vol. 28, No. 5, pp. 711-719, May, 1980.

[6]J. M. Mcquillan, D. C. Walden, *The Arpanet work design deci-*

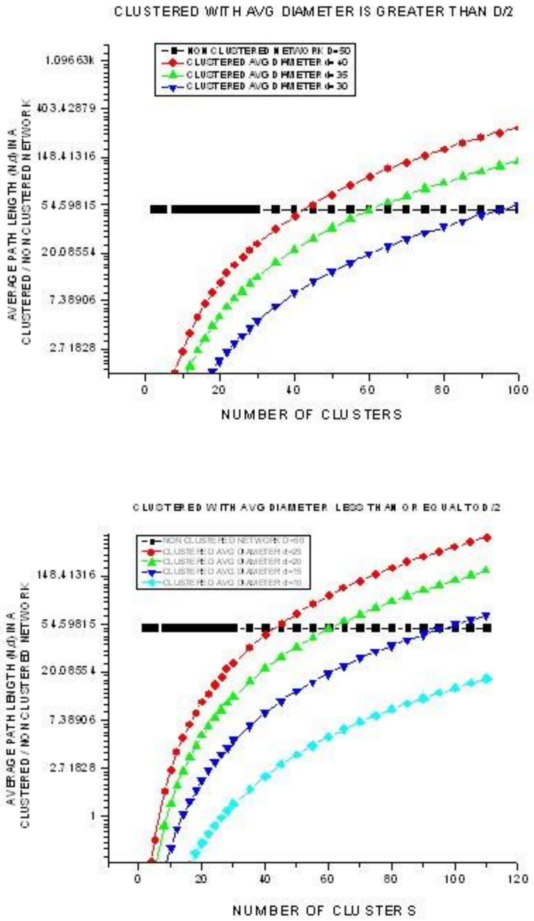

Fig. 6. Path Length (Upper bound) with respect to$D$

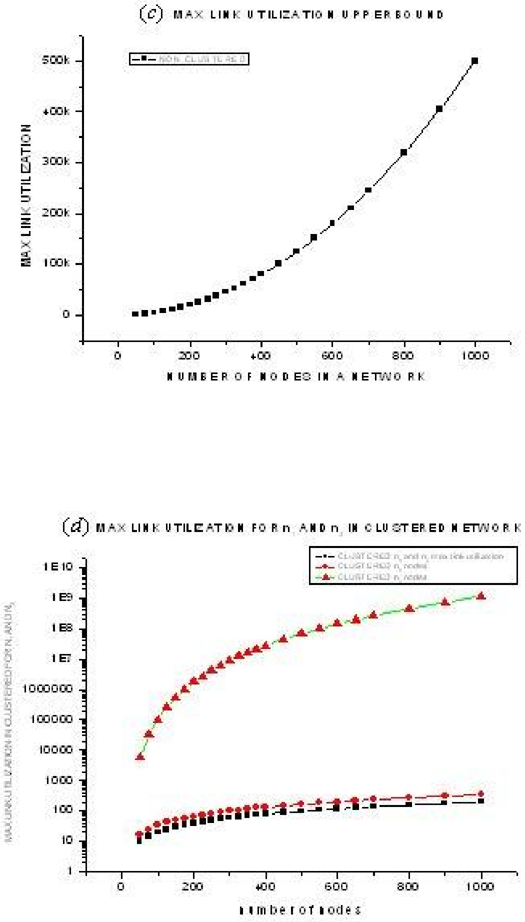

Fig. 7. Maximum Link Utilization (c) and (d) (upper bound)

sions,Computer Computer networks, vol.1,No.5, pp. 243-289, August, 1977.

[7]M. Schwartz, T. E. Stern, *Routing Techniques used in Communication Networks*, IEEE Trans. On Communications, pp. 539-552, April, 1980.

[8]C. Perkins, P. Bhagwat, *Highly Dynamic Destination Sequenced Distance Vector Routing (dsdv) for Mobile Computers*, Proc. Acm Sigcomm Symposium on Communication , Architectures and Protocols, pp. 234-244, September, 1994.

Hemanth Kumar A.R graduated from the Manipal Institute of Technology, Manipal, Karnataka, INDIA in 1999 and received MTech in Digital Communication from B.M.S College of Engineering, Bangalore , Karnataka, INDIA in 2003.Currently he is pursuing PhD in the Department of Electronics and Communication Engineering at MIT Manipal. His current research interest includes Graph Labeling, Clustering the Networks, Partitioning the networks, Connectivity, Path planning , Routing in clustered networks and their application to wireless communication.

Sudhakar G graduated in Bachelor of Science from the Mangalore University, Karnataka (India) in the year 1984 and received M.Sc and MPhil degree from Mangalore University, Karnataka, INDIA in the year 1986 and 1987 respectively and PhD in Graph Theory from Mangalore University, Karnataka, INDIA in the year 2001. His current research interest includes Graph Theory, Linear algebra and Combinatorics

Satyanarayana B.S obtained his PhD (Electrical Engineering) from Cambridge university, UK. He has worked in India and abroad with collaborations in industry, R& D labs and research institutions from UK,Japan,US,Korea and Russia. He has over 70 research publications. His area of interest includes Nano Technology, Novel Electronics Materials and Devices, Vacuum Nano Electronics , Large Area Micro Electronics and Flexible Electronics, Flat panel display,MEMS,Networks,Sensors, Energy harvesting and Energy conversion technologies.Currently he is the principal of RV college of Engineering, Bangalore,India.

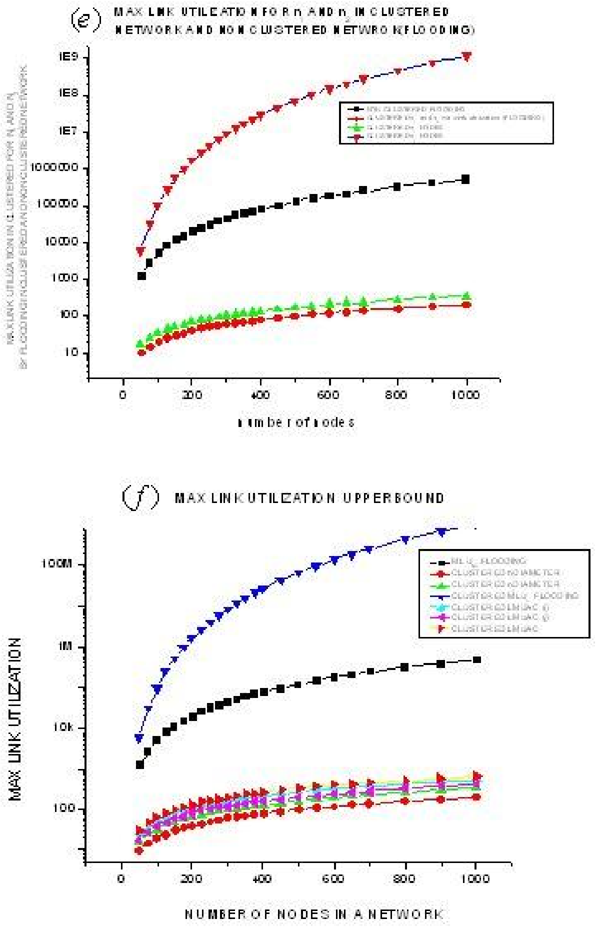

Fig. 8. Maximum Link Utilization (e) and (f) (upper bound)

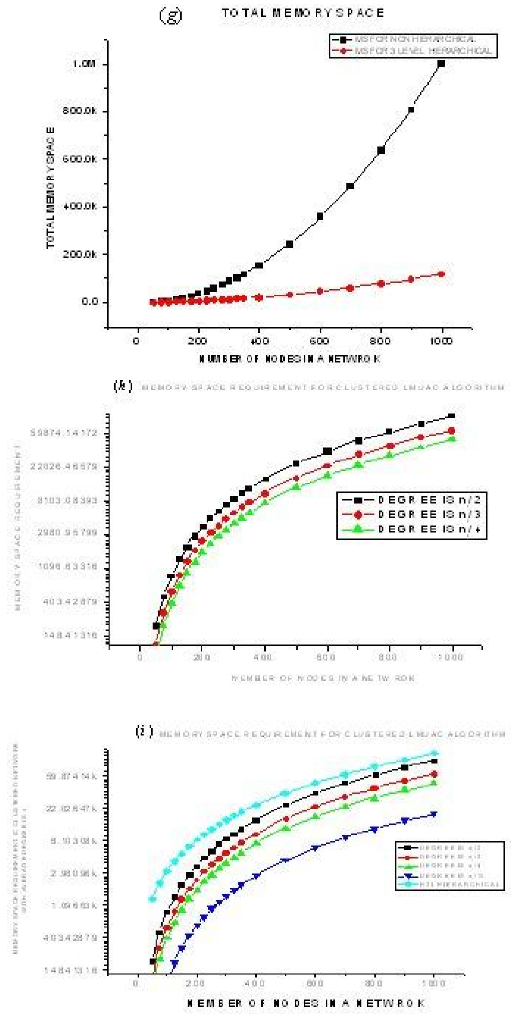

Fig. 9. Memory Space Requirement (upper bound)