DEPARTMENT OF INFORMATION TECHNOLOGY

A

SEMINAR REPORT

ON

HYPOCOMB: BOUNDED-DEGREE LOCALIZED GEOMETRIC PLANAR GRAPHS FOR WIRELESS AD-HOC NETWORKS.

OF

T.E. (INFORMATION TECHNOLOGY)

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(2014-2015)

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CERTIFICATE

This is to certify that a seminar titled

“ HYPOCOMB: BOUNDED-DEGREE LOCALIZED
GEOMETRIC PLANAR GRAPHS
FOR WIRELESS AD-HOC NETWORKS.”

has been completed by **Mr Vedang. R. Joshi** (Roll No. 3828) of TE IT in the Semester - II of academic year 2014-2015 in partial fulfillment of the Third Year of Bachelor degree in “Information Technology” as prescribed by the SavitriBai Phule Pune University.

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Place: PICT, Pune
Date: / 03 / 2015

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It gives me great pleasure and satisfaction in presenting this seminar on "HYPOCOMB: BOUNDED-DEGREE LOCALIZED GEOMETRIC PLANAR GRAPHS FOR WIRELESS AD-HOC NETWORKS".

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Mr. Vedang. R. Joshi

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ABSTRACT

In this paper authors try to inspect the properties of the novel Hypocomb family graphs and study their impact on FACE routing protocol in comparison with Del, LDel, GG through extensive simulations. Similarly they also conclude the observations made in the paper. They prove that Hypocomb has unbounded degree,while RHC and LHC are bounded above by 6 and 8 respectively through simulations.

The FACE simulations were carried over custom simulator on exactly same random node distribution. These simulations help us compare impact of complete graph, UDG and DEL, HC, RHC, LHC etc. In FACE routing using: maximum degree,Avg. Hop count,Avg. Degree,Avg. Hop length and Spanning ratio. The resulting graphical representation also provides interesting insights into the properties of Hypocomb family graphs. They evaluate Hypocomb family of graphs and observe their usefulness in routing. Certain open research areas are evaluated as open research prospects.

An attempt is made by us to study the effect of using Hypocomb family graphs in FACE routing toward energy conservation in Wireless ad-hoc Networks.

Keywords : DEL, HC, RHC, LHC, FACE routing, Wireless ad-hoc Networks

LIST OF FIGURES

LIST OF ABBREVIATIONS

ABBREVIATION	**ILLUSTRATION**
GG	Gabriel Graph
LDel	Localized Delaunay
LHC	Localized Hypocomb
UDG	Unit Disk Graph
HC	Hypocomb
RHC	Reduced Hypocomb
Del	Delaunay
MST	Minimum Spanning Tree
GFG	Greedy-FACE-Greedy

CHAPTER 1

Introduction

1.1. Motivation

Motivation of this seminar is to study the numerical results computed by the authors as applied on Hypocomb family of Graphs. The novelty of the Hypocomb family of graphs is the point to be stressed. This is an attempt to study the effect of using Hypocomb graphs on FACE routing protocol in terms of their maximum and average degree, average hop count, average hop length and spanning ratio. There is an attempt to study the various types of face routing algorithms and also the combinations of face and other algorithms. This will help us better understand impact of Hypocomb family graphs in ad-hoc routing.

1.2. Problem Statement

Study of the numerical results of FACE routing protocol when applied to Hypocomb family graphs, Del, LDel, GG. Study of FACE Routing protocol and the Greedy-FACE-Greedy Protocol.

1.3. Scope

The paper referred deals with the impact of Hypocomb family graphs on Face routing in terms of maximum degree of graph, number of hops, average hop length, spanning ratio. The paper also deals with the GFG protocol, one of many routing protocols combined for forwarding and recovery from local maxima [1]. The paper stays confined to the technical specifications of the Hypocomb family graphs and gives a brief overview of the possible applications of these graphs.

CHAPTER 2

Literature Survey

2.1. FACE AS A RECOVERY ALGORITHM

Name of Area :- Graphs and Networks

Seminar Topic :- Hypocomb: Bounded-Degree Localized Geometric Planar Graphs for Wireless Ad Hoc Networks

Name of Paper :- Routing with Guaranteed Delivery in Ad Hoc Wireless Networks.

Summary :- The authors consider routing problems in ad hoc wireless networks modeled as unit graphs in which nodes are points in the plane and two nodes can communicate if the distance between them is less than some fixed unit. An outcome of the paper is a simple distributed protocol for extracting a planar subgraph of a unit graph. Authors also provide simulation results on the performance of our algorithms.

2.1.1. Explication

An algorithm for finding out the planar sub-graph of a given graph is given by the authors. Two algorithms for routing in planar graphs are given by the authors, viz. FACE-1 and FACE-2.

<u>FACE-1 Algorithm</u> -

```
p ← s
repeat
    let f be the face of G with p on its boundary
    that intersects line segment (p, t)
    for each edge (u, v) of f
```

```
          if (u, v) intersects (p, t) in a point p and
                dist(p , t) < dist(p, t)
                p ← p
          end if
  end for
 Traverse f until reaching the edge (u, v) containing p
  until p = t
```

FACE-2 Algorithm -

```
p ← s
repeat
        let f be the face of G with p on its boundary
        that intersects (p, t)
        traverse f until reaching an edge (u, v) that
        intersects (p, t) at some point p = p
        p ← p
 until p = t
```

2.1.2. Results :- The results of combining the GEDIR algorithm with FACE -2 by applying the GEDIR algorithm until it either fails or reaches the destination. If the GEDIR algorithm fails, routing is completed using the FACE-2 algorithm. In this scenario FACE-2 can be viewed as acting as a backup for the GEDIR algorithm. We refer to this algorithm as GEDIR + FACE-2. Thus face routing is generally used in association with other protocols as a recovery mechanism.

2.2. DELIVERY GUARANTEE AND FACE SELECTION ALGORITHMS

Name of Area :- Graphs and Networks

Seminar Topic :- Hypocomb: Bounded-Degree Localized Geometric Planar Graphs for Wireless Ad Hoc Networks.

Name of Paper :- Hannes Frey and Ivan Stojmenovic, “On Delivery Guarantees and Worst- Case Forwarding Bounds of Elementary Face Routing Components in Ad-Hoc and Sensor Networks”, IEEE TRANSACTIONS ON COMPUTERS,VOL. 59, NO. 9, SEPTEMBER 2010.

Summary :- In this paper the authors study delivery guarantees, loop-free operation of face and combined greedy-face routing variant protocol. The authors show that for planar graphs, recovery from a greedy routing failure is always possible without changing between any adjacent faces. Guaranteed delivery thus follows from recovery while traversing the very first face. In arbitrary planar graphs, however, a proper face selection mechanism is of importance since recovery from a greedy routing failure may require visiting a sequence of faces before greedy routing can be restarted again. They also discuss the reasons why other methods fail to deliver a message or even end up in a loop. In addition, they investigate the behavior of face routing in arbitrary not necessarily planar networks and show, while delivery guarantees cannot be supported in such a general case, most face and combined greedy-face routing variants support at least *loop-free* operation.

Explication :-

The various face routing variants are discussed are :

1. Greedy-face-greedy (GFG)
2. Compass routing II (CR)
3. Greedy perimeter stateless routing (GPSR)
4. Other face routing (OFR)
5. Greedy path vector face routing (GPVFR)

Results :- The outcome is a comparative study of delivery guarantees of face routing algorithms when applied on their own. These results are later used in to
show that the combination of greedy and other face routing variants provide delivery guarantees.

CHAPTER 3

Discussion and Analysis

3.1. Overview

A wireless ad-hoc network consists of a collection of nodes that communicate with each other through wireless links without a pre-established networking infrastructure. It originated from battlefield communication applications, where infrastructure networks are often impossible. Due to its flexibility in deployment, there are many potential applications of a wireless ad-hoc network. For example, it may be used as a communication network for a rescue-team in an emergency caused by disasters, such as earthquakes or floods, where fixed infrastructures may have been damaged[5].

3.1.1 . Routing in Wireless Ad-Hoc Networks

In a data communication network, if two nodes are not connected directly by a communication link, their messages to each other need to be forwarded by intermediate nodes. Finding a path between two nodes on which to send messages in data communication networks is a fundamental problem, called *routing*. In wireless ad-hoc networks, nodes are not only hosts, but also function as routers to forward messages to other nodes that are not within direct wireless transmission range of each other. The participating nodes form a self-organized network without any centralized administration or support. Therefore, wireless ad-hoc networks are *purely distributed systems* [5].

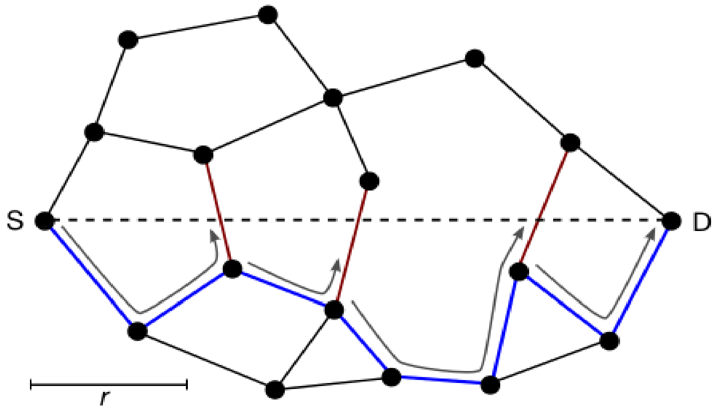
When a node receives a packet, the simplest way to route the packet is to forward it to the neighbor that is closest to the destination. This is called *greedy routing* [3]. Compared to other protocols, greedy routing has extremely low routing overhead and scales well to large networks. However, greedy routing may fail to deliver a packet, because the packet may reach a node whose neighbors are all farther away from the destination.

A technique called *face routing* provably guarantees packet delivery in static connected plane graphs. Face routing is applied on a planar graph, and the packet is forwarded along the boundaries of the faces that are intersected by the line segment between the source node and the destination node. The face routing protocols in the literature have the following two constraints: they need a separately constructed spanning plane subgraph of the network for routing, and they assume that the planar subgraph remains static during the routing process. Experimental results indicate that most existing algorithms have problems in real wireless networks due to radio range irregularities and imprecise location information. Problems with the resulting routing graph can lead to failure of face routing protocols [1].

3.1.2 . Face Routing

Face routing was the first geometric routing algorithm that guaranteed message delivery without flooding. Several variants of face routing protocols were subsequently proposed. Face routing is applied on a plane subgraph of the network graph. A plane graph divides the plane into faces. The line segment between the source node and the destination node intersects some faces. In face routing, the packet is forwarded along the boundaries of these faces. A specific face routing protocol provides a set of rules for each node to decide where to send a packet using only the local information about its neighbors and the information in the packet header [2].

A typical face routing protocol works as follows : When face routing starts, the packet is forwarded along the boundary of the first face intersected by the line segment from the starting point to the destination. The first edge of the traversal of a face is the first edge in clockwise order around the starting point from the line segment to the destination. After the traversal of an edge (u, v), the next edge of the face traversal is the first edge after (v, u) in clockwise order around v. In this way, the packet traverses the edges on the boundary of the face in the counterclockwise direction. The traversal in this way is called the right-hand rule. When the traversal reaches an edge that intersects the line segment from the starting point to the destination at a point closer to the destination than the starting point is, that point becomes the new starting point and the traversal switches to the next face. This procedure repeats until the destination is reached [2].



Face routing: A message is routed along the interior of the faces of the communication graph, with face changes at the edges crossing the S-D-line (red). The final routing path is shown in blue.

Fig. 3.1 Face Routing *[4]*

Greedy forwarding can lead into a dead end, where there is no neighbor closer to the destination. Then, face routing helps to recover from that situation and find a path to another node, where greedy forwarding can be resumed. A recovery strategy such as face routing is necessary to assure that a message can be delivered to the destination. The combination of greedy forwarding and face routing was first proposed in 1999 under the name GFG (Greedy-Face-Greedy) [3]. It guarantees delivery in the so-called unit disk graph network model.

3.2 . Explication

The Face routing protocol was applied to various types of Graphs with same number of nodes [1]. The performance was measured by the authors using the following metrics:

3.2.1 Maximum Degree

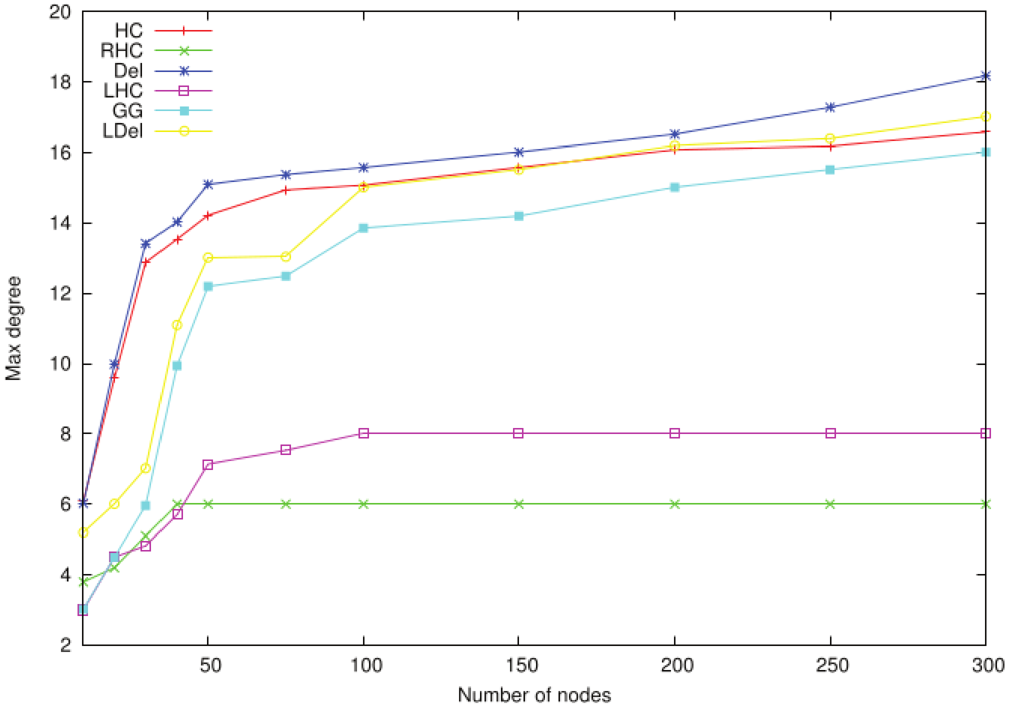


Fig. 3.2.1 Maximum Degree of RHC and LHC [1]

HC has unbounded degree. The degree of RHC and LHC is bounded above by 6 and 8 respectively. Lower degree implies lower density and lower network traffic [1].As is evident from the degree of LHC and RHC grows generally till n=40 and n=100 for RHC and LHC respectively.There is a vast gap in the degree of LHC,RHC as oppposed to other contemporary graphs.This is an evidence of the novelty of this Graph family [1].

3.2.2. Average Degree

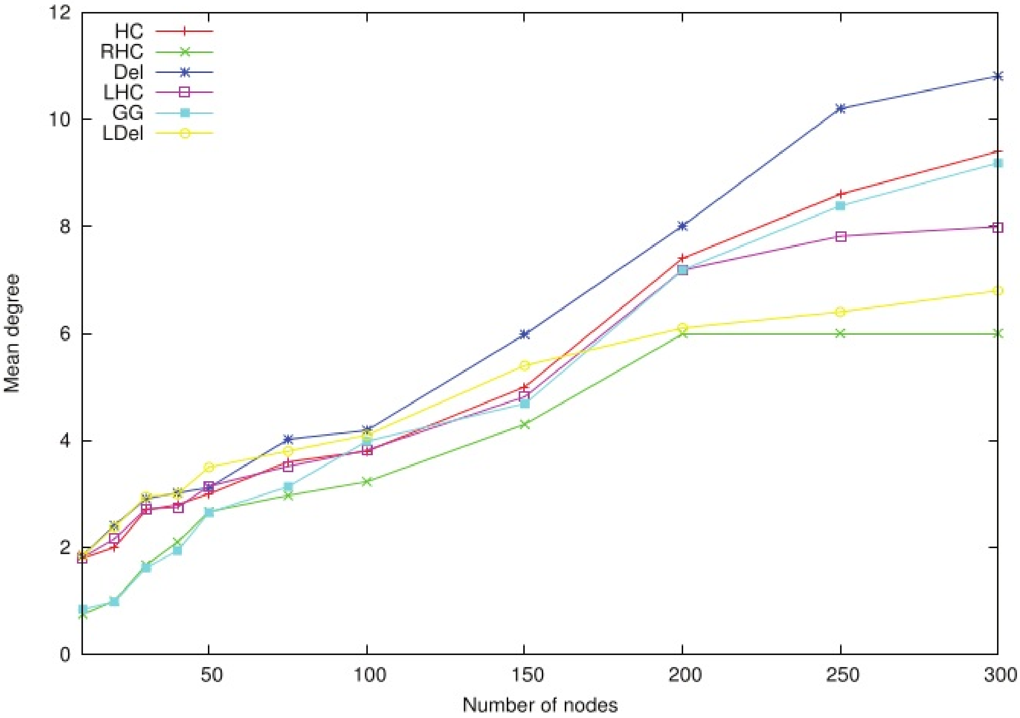


Fig. 3.2.2 Average Degree of Graphs [1]

Fig. 3.2.2 shows the average degree reflecting how sparse or dense a graph is, which as expected slowly increases with the overall number n of nodes. For RHC and LHC, it never exceeds the corresponding degree bound. We observe that their curves become flat after a turnover point of n = 200, 250 respectively. Among them Del and RHC are, respectively, the densest and the sparsest. LDel, GG, and LHC are both local graphs and thus competitors. LHC is a bit denser than GG for before n = 250 and becomes increasingly sparser afterwards as GG has no degree bound. On average, LDel is the densest before n = 200 and then the sparest on average [1].

3.2.3. Average Hop Count

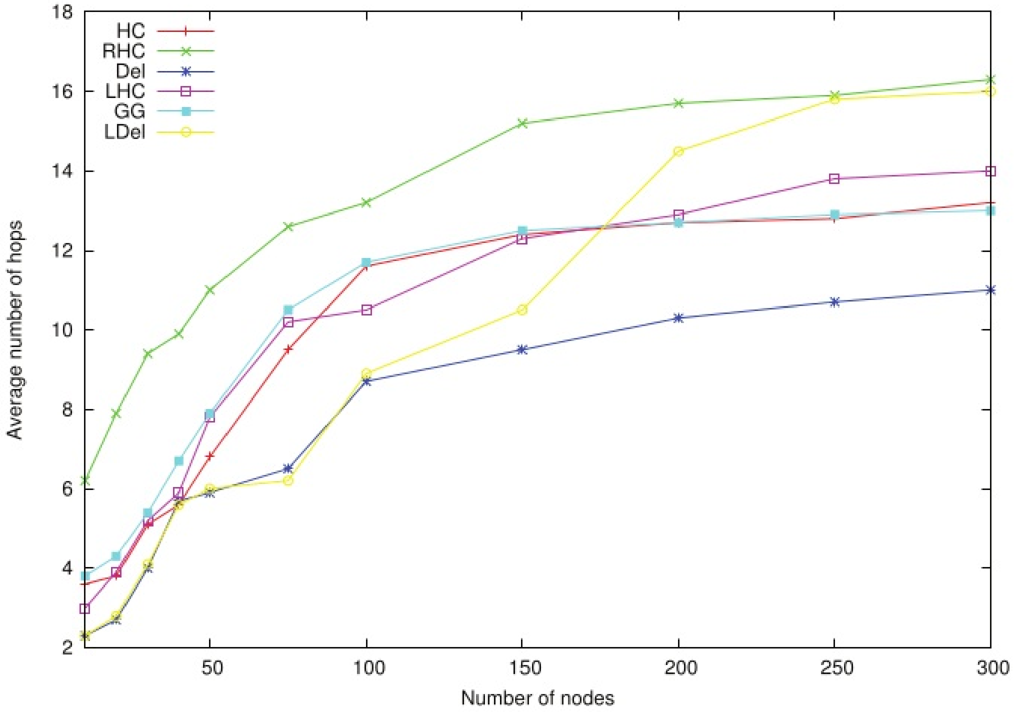


Fig. 3.2.3 Average hop count [1]

Generally speaking, the denser a graph, the higher the degree of the graph, and the smaller the average face size in the graph. Hence, as n goes up, FACE is expected to produce increasingly long paths, in terms of hop count, which are composed of shorter and shorter hops. This is confirmed by the ascending trend of the curves in Fig. 3.2.3 [1]

3.2.4. Average Hop Length

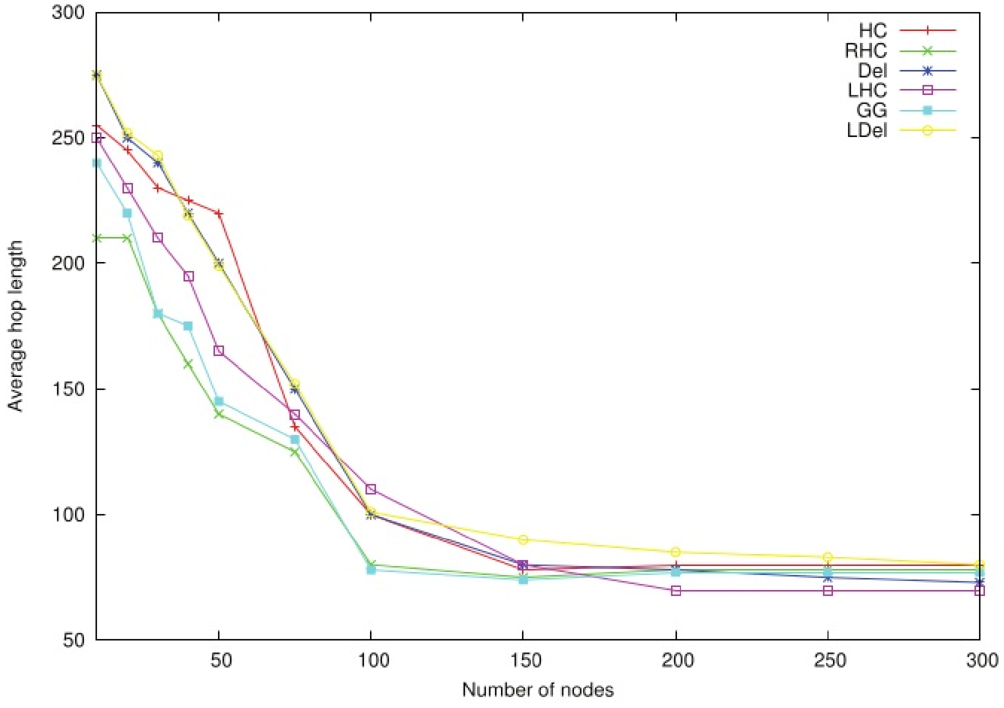


Fig.3.2.4 Average Hop Length [1]

Denser a graph, the higher the degree of the graph, and the smaller the average face size in the graph. Hence, as n goes up, FACE is expected to produce increasingly long paths, in terms of hop count,which are composed of shorter and *shorter hop length* [1].

3.2.5. Spanning Ratio

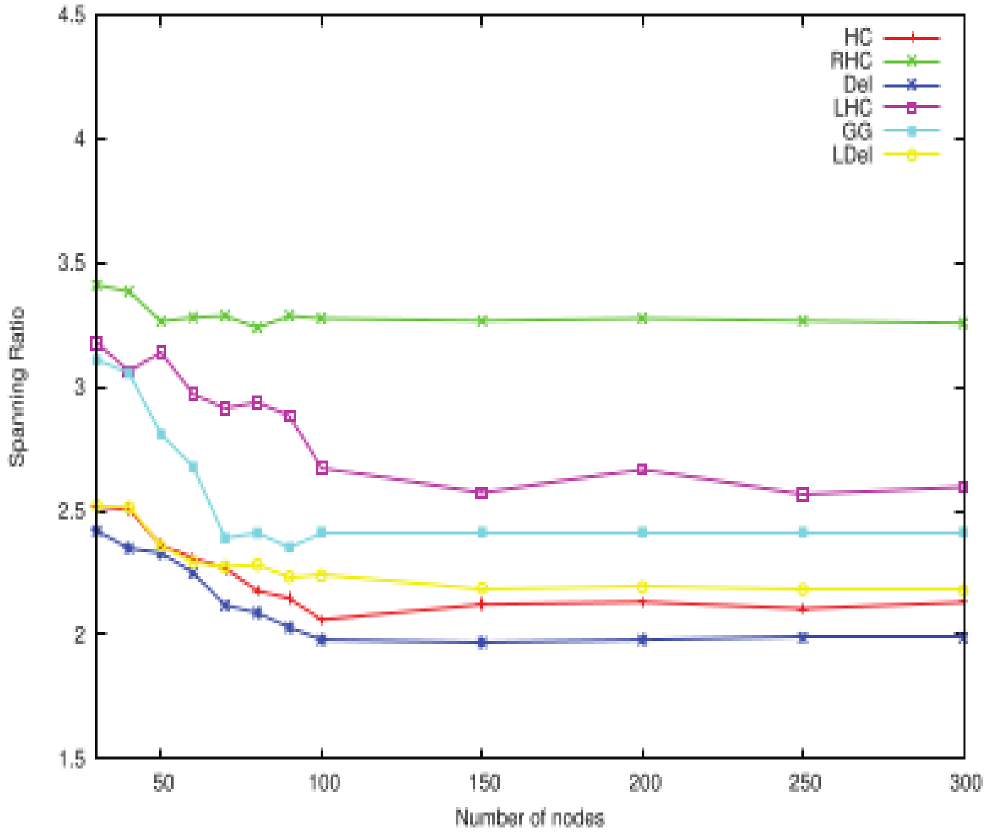


Fig. 3.2.5 Spanning Ratio [1]

As *planarisation* removes crossing edges it may induce *detours* due to missing edges. Therefore, such planar subgraph constructions are desired that approximate the original graph as closely as possible. This property can be formally described by the so-called *spanning ratio* or *stretch factor* [1]. The maximum ratio of the shortest path length between two nodes u and v in the subgraph over the shortest path length between u and v in the original graph. A desired property is a *constant stretch factor*, as it guarantees a constant overhead for any path in the subgraph [1].

3.3. Results

After reading the paper I can conclude that the Hypocomb graphs are indeed novel. The RHC and LHC due to their reduced degree offer better support to face routing than the other graphs such as GG, Del, LDel etc.

The 6 and 8 degrees of LHC and RHC respectively are particularly useful in reducing the density of graphs and thus helping in reducing the unnecessary traffic. The combination of Greedy and face routing in wireless ad hoc networks leads to guaranteed delivery through recovery when packet reaches local maxima.

The reduced average hop length and number of hops leads to faster packet delivery and reduced overhead traffic. The reduced traffic overhead may lead to a decreased power consumption. This is very important in wireless networks due to the fact that the actor nodes are powered through limited battery packs. The reduced energy consumption leads to a longer field life for the nodes leading to saving of efforts in replacing them from time to time.

CHAPTER 4

FINDINGS, CONCLUSION AND FUTURE SCOPE

4.1. FINDINGS

4.1.1. Reasons of energy consumption in the network [6]:

In wireless ad hoc and sensor networks, nodes dissipate energy in processing, transmitting and receiving messages. This energy is needed for correct working of the wireless networks. In addition to this energy, there is a great amount of energy wasted in states that are useless from the application point of view, such as:

(a) ***Idle listening***: since a node does not know when it will receive a message it must permanently listen to the medium and so it remains in the idle state.

(b) **O*verhearing***: When a sender transmits one packet to next hop, because of the shared nature of wireless medium, all neighbors of the source receive this packet even if it is intended to only one of them. Thus the overhearing is the energy dissipated when the node is an one-hop neighbor of the sender and is not the destination.

(c) **I*nterference***: Each node situated between transmitter range and interference range receives this packet but it cannot decode it.

(d) ***Collision:*** When a collision occurs, the energy dissipated for the transmission and for the reception of colliding frames is wasted.

Outcome : As the authors have proved that the Hypocomb graphs are sparsest among most of the planar graphs the factors 4.1.1(b) reduced. As the number of nodes in the transmission range of the nodes is reduced there is a decrease in 4.1.1(c) and 4.1.1(d).

4.1.2. Energy consumption model [6]:

Many energy consumption models proposed in the literature. We can these unify models by the following one highlighting two components of the energy dissipated by the transmitter. The first component reflects the energy consumed by the radio. The second component presents the energy consumed by the amplifier and depends on the distance between the transmitter and the receiver.

$$
\begin{aligned}
E\ transmit &= C\,1\,(size) + C\,2\,(size, d) \\
&= C\,1 \cdot size + C\,2 \cdot size \cdot d^{\alpha} \\
&= size(C\,1 + C\,2 \cdot d^{\alpha}), \quad \ldots\ldots\ldots\ldots\ldots..(1)
\end{aligned}
$$

where,

C 1 : Energy consumed by the radio of the transmitter to transmit a bit,

C 2 : Energy consumed by the amplifier to send a bit at a distance of 1 meter,

size : Packet size,

d : Distance between the transmitter and the receiver,

$0 < \alpha < 6$ values of 2 or 4 are the most frequently used.

Many works about topology control focus on the component proportional to the distance. Equation 2.1 becomes, when uniformed by the size of the transmitted packet:

$$E\ transmit = C\,1 + C\,2 * d^{\alpha}\ , \ldots\ldots\ldots\ldots\ldots\ldots\ldots..(2)$$

This formula points out the relation between energy consumption and distance. This relation is used in topology control to optimize energy consumption by tuning the transmission power taking into account the distance between the transmitter and the receiver. Many other works suppose that the transmissions is done at the maximum power. In other words, the transmitter uses the transmission power such that any receiver at a distance equal to the transmission rage correctly receives the message. Consequently, we can consider the quantity ($C\ 1 + C\ 2 \cdot d\ \alpha$) as a constant named C.

Hence, the energy dissipated in a transmission by a transmitter is :

$$E\ transmit = C \cdot size\ , \quad \ldots\ldots\ldots\ldots\ldots(3)$$

where size denotes the packet size in bits. In reviewed work, we assume that: the transmission power is a constant and the same for all nodes in the network.

Outcome : As the average hop length decreases the most for Hypocomb the energy required to transmit is reduced and thus there is a scope for energy saving.

4.2. CONCLUSION

In this paper, the authors focus on geometric planar graphs and their use in Wireless Ad Hoc Networks. For this, they propose a radically new family of geometric planar graphs, completely different from any known graph, and focus on their theoretical properties.

They first introduce Hypocomb (Hypotenuse-comb), which is the “dual” of a truncated mesh referred to as Besh (Blocked-mesh). Hypocomb has unbounded degree. They then propose Reduced Hypocomb and Local Hypocomb, the two new graphs derived from Hypocomb.

RHC and LHC, both have an impressive degree bound of 6 and 8 respectively. Also, the authors claim that LHC is the first strictly localized, degree-bounded planar graph computed using merely 1-hop neighbor position information. This could well be a great breakthrough in Wireless Ad Hoc Networking in terms of efficient architecture for routing.

The authors plan to make use of these graphs in Hypocomb graph family in Wireless Ad Hoc Networking. But there exist open practical problems brought by Hypocomb family graphs. sensors form a connected network; actor nodes are generally multi-hop away from each other. In the resulting Besh, edges are multi-hop routing paths composed of sensors. The idea is to simulate the ray drawing process from each actor by directional message transmission, which is realized by Greedy-FACE-Greedy (GFG) routing. 17

Hypocomb and Reduced Hypocomb may be constructed with minor modification to the existing algorithm as follows: each node where blocking happens informs the sender actors about the blocking so that the latter know about who they are blocking and whom they are blocked by. The goal is to obtain an overlay network bearing planar topology among actors so that existing communication protocols can be run directly, or with minor modification, on it to realize.

Indeed, Hypocomb and Reduced Hypocomb are promising for the emerging field of wireless sensor and actor networking. Both Reduced Hypocomb and Local Hypocomb may be used for *Bluetooth Scatternet* formation. When Local Hypocomb is applied, in each comprising *Piconet* there is at most one parked node. As revealed by the simulation study made by the authors, Local Hypocomb is promising for localized greedy-face combined ad hoc routing.

We attempt to propose a method of realizing the HC construction in real WSN. This can be done using GPS System pre-existing in the WSN Nodes. The details have been included in the Future Scope.

We also conclude from all the study made and numerical results available that HC Family Graphs help to reduce the average hop count, average hop length and even average degree as compared to existing graph families. Energy efficiency in WSNs is equal to Amount of Data Delivered/Energy Stored. As we very well know, the energy stored in the WSN Nodes has a constraint due to the dimensions of general nodes. So, to increase the energy efficiency of the network, the only feasible option available is to reduce the net amount of data delivered by the nodes in the WSN. By the use of HC Family Graphs, we can ensure that the total amount of data.

4.3. FUTURE SCOPE

The diversity of the applications supported by wireless ad hoc and sensor networks explains the success of this type of network. These applications concern with various domains as environmental monitoring, wildlife protection, emergency rescue, home monitoring, target tracking, exploration mission in hostile environments, etc. However, the most critical requirement for adopting such networks is energy efficiency. Indeed,18 some nodes are battery operated and battery replacement can be difficult, expensive or even impossible. The goal of communication protocol designers is then to maximize the lifetime of such networks.

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