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A SURVEY ON AREA PLANNING FOR HETEROGENEOUS NETWORKS

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ABSTRACT

This paper deals with the survey of basic networks like Spidergon network and Honeycomb Torus network with respect to network cost. The basic network can be modelled in different structures to overcome the problems in handling the user density patterns, utilizing the available bandwidth effectively and improvising the efficiency. These bottlenecks are overcome by selecting the proper structure for a particular network based on network cost. In this paper the efficiency of specified network is estimated with respect to the number of nodes.

KEYWORDS

Honeycomb Network, Hexagonal Network, Spidergon network, Honeycomb Torus network, Spidergon topology, Honeycomb Torus topology, degree, diameter, network cost.

1. INTRODUCTION

An interconnection network consists of set of nodes and communication links for the data transmissions. For instance multiprocessor interconnection networks are often required to connect thousands of homogeneously replicated processor-memory pairs, each of which is called a processing node. Synchronisation and communication between processing nodes is effectively implemented by message passing [1]. As the cost of powerful microprocessors and memory chips are less expensive, design and use of multiprocessor interconnection networks has drawn considerable attention [2]. The three basic tessellations such as triangular, square, and hexagonal can be used to design interconnection networks. Grid networks (Figure 1(a)) are built by using the square tessellations. The applications of grid networks are interconnection of computers and servers and for parallel processing. The honeycomb networks (Figure 1(c)) are built by using the hexagonal tessellation. The applications of honeycomb networks are computer graphics [3], image processing [4], cellular base stations [5], representation of benzenoid hydrocarbons and many more. The hexagonal network (Figure 1(d)) is built by using the triangular tessellation. The applications of hexagonal networks are tracking mobile users and connection rerouting in cellular networks [6]. The torus networks (Figure 1(b)) are built by using the honeycomb structure with wraparound connections. The applications of torus networks are interconnection of computers with minimized network cost.

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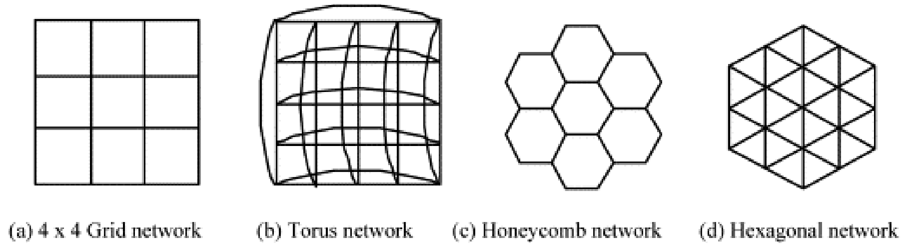

Figure1. Graphs obtained by regular plane tessellations

If the interconnection is analyzed as a graph, each vertex represents a node and each edge represents a link between nodes. The degree of a node is defined as the number of adjacent nodes and it is almost equivalent to the hardware cost of an interconnection. The diameter in an interconnection network is the maximum distance of the shortest path between two randomly selected nodes and it is almost equivalent to the software processing cost of an interconnection. As the degree and diameter are inversely proportional, the higher the value of the diameter it results in a non-efficient interconnection, which in turn results in traffic latency, as the deadlock probability increases in the progress of the message transmission [7]. The network cost is defined as the product of degree and diameter [8]. A good interconnection network is expected to have least number of edges, minimum network cost and high reliability [9].

In this paper, the network costs of the Spidergon network and Honeycomb Torus network are compared. The degree and the diameter are the parameters considered for evaluation. The analysis is used to discover the application of the two specified networks.

The rest of the paper is organized as follows: Section 2 describes the related works. In Section 3, we describe the Spidergon network [10]. Section 4 presents the description of Honeycomb Torus network [8]. Section 5 discusses about the area planning [11]. Section 6 compares the network cost for the above two networks. The conclusion is given in Section 7.

2. RELATED WORKS

The size of the interconnection connection network increases as the size of the number of nodes increases. The interconnection network has fixed degree in networks like mesh and torus regardless of the increase of the number of the nodes. There are some interconnection networks like hypercube and star in which the degree changes as the number of nodes are increased.

In 1997 Ivan Stojmenovic [8] has compared the network cost of various mesh, torus and hypercube networks with respect to the number of nodes. The comparison of the class of the mesh in the viewpoint of the network cost based on the number of nodes is the following (Table 1): For a mesh network the number of the degree is 4, the number of the node is n and the network cost is $8\sqrt{n}$. The hexagonal mesh arranges the triangle with the type of tessellation continuously and the lattices are the node. The number of the degree is 6, the number of node is n, and the network cost is $6.93\sqrt{n}$. The honeycomb mesh is the structure which arranges the hexagon in the side of the hexagon which exists in the center and expands the network, the number of the degree is 3, the number of the node is n, and the network cost is $4.9\sqrt{n}$. The torus is the network which adds the wrap around edges at the row and the column of the mesh respectively to achieve the ring structure. The diameter and the network cost of the torus are decreased 1/2 of the mesh, the number of the degree is 4, the number of the node is n and the network cost is $4\sqrt{n}$. The hexagonal torus is the network which adds the wrap around edges to the hexagonal mesh, the number of the degree is 6, the number of the node n, and the network cost is $3.46\sqrt{n}$. The honeycomb torus is the structure which adds the wrap around edges to the honeycomb mesh, the number of the degree is 3, the number of the node is n and the network cost is $2.45\sqrt{n}$. Similarly the network cost is calculated for other networks defined in Table1.

Table 1. Comparison of Network Cost based on number of nodes

Network	Degree	Diameter	Cost	Bisection Width
Mesh Connected	4	$2\sqrt{n}$	$8\sqrt{n}$	$\sqrt{n}$
Hexagonal Mesh	6	$1.16\sqrt{n}$	$6.93\sqrt{n}$	$2.31\sqrt{n}$
Honeycomb Mesh	3	$1.63\sqrt{n}$	$4.9\sqrt{n}$	$0.82\sqrt{n}$
Torus	4	$\sqrt{n}$	$4\sqrt{n}$	$2\sqrt{n}$
Hexagonal Torus	6	$0.58\sqrt{n}$	$3.46\sqrt{n}$	$4.61\sqrt{n}$
Honeycomb Torus	3	$0.81\sqrt{n}$	$2.45\sqrt{n}$	$2.04\sqrt{n}$
Honeycomb Rhombic Mesh	3	$2.83\sqrt{n}$	$8.49\sqrt{n}$	$0.71\sqrt{n}$
Honeycomb Square Mesh	3	$2\sqrt{n}$	$6\sqrt{n}$	$0.5\sqrt{n}$
Honeycomb Rhombic Torus	3	$1.06\sqrt{n}$	$3.18\sqrt{n}$	$1.41\sqrt{n}$
Honeycomb Square Torus	3	$\sqrt{n}$	$3\sqrt{n}$	$\sqrt{n}$
Hypercube	log n	log n	$\log^2 n$	n/2
Cube Connected Cycles	3	O(log n)	O(log n)	O(*n*/log n)
Butterfly	4	O(log n)	O(log n)	O(*n*/log n)
DeBruijn	4	O(log n)	O(log n)	O(*n*/log n)

In 2009 Woo-seo Ki et al., [7] has compared the network cost of some networks based on dimension n X n. The comparison of the class of the mesh in the viewpoint of the network cost based on dimension is the following (Table 2): For a mesh network the number of the degree is 4, the number of the node is $N = n^2$ and the network cost is $8\sqrt{N}$. The hexagonal mesh has the number of the degree is 6, the number of node is $N = 3n^2-3n+1$, and the network cost is $6.93\sqrt{N}$. The honeycomb mesh has the number of the degree is 3, the number of the node is $N = 6n^2$, and the network cost is $4.9\sqrt{N}$. The torus network has the number of the degree is 4, the number of the node is $N = n^2$ and the network cost is $4\sqrt{N}$. The hexagonal torus has the number of the degree is 6, the number of the node $N = 3n^2-3n+1$, and the network cost is $3.46\sqrt{N}$. The honeycomb torus has the number of the degree is 3, the number of the node is $N = 6n^2$ and the network cost is $2.45\sqrt{N}$.

Table 2. Comparison of Network Cost based on dimension and number of nodes

Network	No of nodes (N) based on dimension	Degree	Diameter	Cost
Mesh Connected	$N = n^2$	4	$2\sqrt{N}$	$8\sqrt{N}$
Hexagonal Mesh	$N = 3n^2-3n+1$	6	$1.16\sqrt{N}$	$6.93\sqrt{N}$
Honeycomb Mesh	$N = 6n^2$	3	$1.63\sqrt{N}$	$4.9\sqrt{N}$
Torus	$N = n^2$	4	$\sqrt{N}$	$4\sqrt{N}$
Hexagonal Torus	$N = 3n^2-3n+1$	6	$0.58\sqrt{N}$	$3.46\sqrt{N}$
Honeycomb Torus	$N = 6n^2$	3	$0.81\sqrt{N}$	$2.45\sqrt{N}$

From the above comparisons it is observed that the Honeycomb Torus network has the lowest network cost and highest bisection width.

In 2009 Paul Manuel and Indra Rajasingh [12] has studied the topological properties of silicate and oxide network. A silicate network is obtained from a honeycomb network *HC*(*n*) as shown in Figure 2(a). Place silicon ions on all the vertices of honeycomb network. Subdivide each edge of honeycomb network once. Place oxygen ions on the new vertices. Introduce 6n new pendant edges one each at the 2-degree silicon ions of honeycomb network and place oxygen ions at the pendent vertices. For every silicon ion associate the three adjacent oxygen ions and form a tetrahedron as in Figure 2(b). The resulting network is a silicate network SL(n). The parameter n of SL(n) is called the dimension of SL(n).

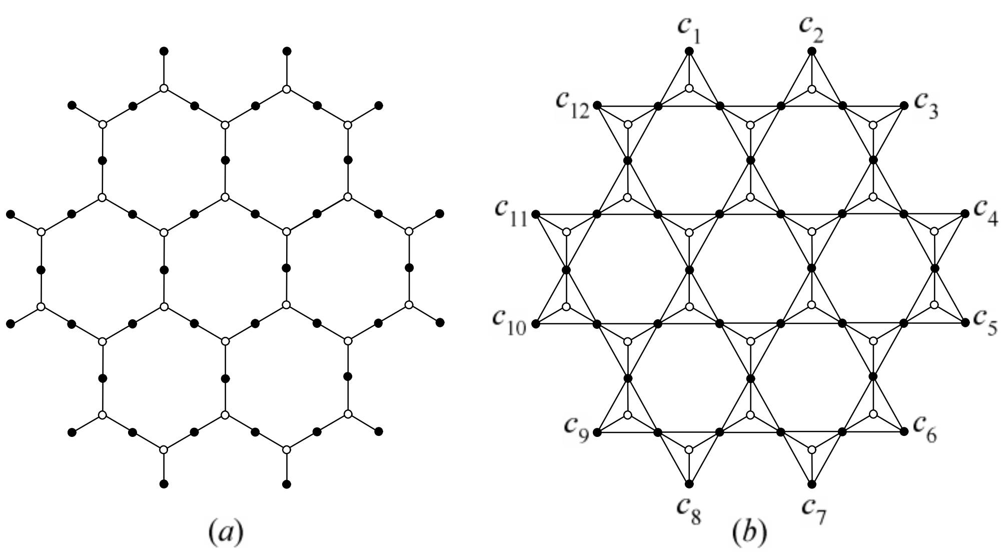

Figure 2. Silicate network construction and boundary nodes

When all the silicon nodes from a silicate network are deleted new network is obtained called as an *Oxide Network* (Figure 3). An *n*-dimensional oxide network is denoted by *OX*(*n*). Even though *HC*(*n*) and *OX*(*n*) are sub graphs of *SL*(*n*), *OX*(*n*) plays more important role in studying the properties of *SL*(*n*). The diameter of silicate network *SL*(*n*) is equal to the diameter of the oxide network *OX*(*n*) [7].

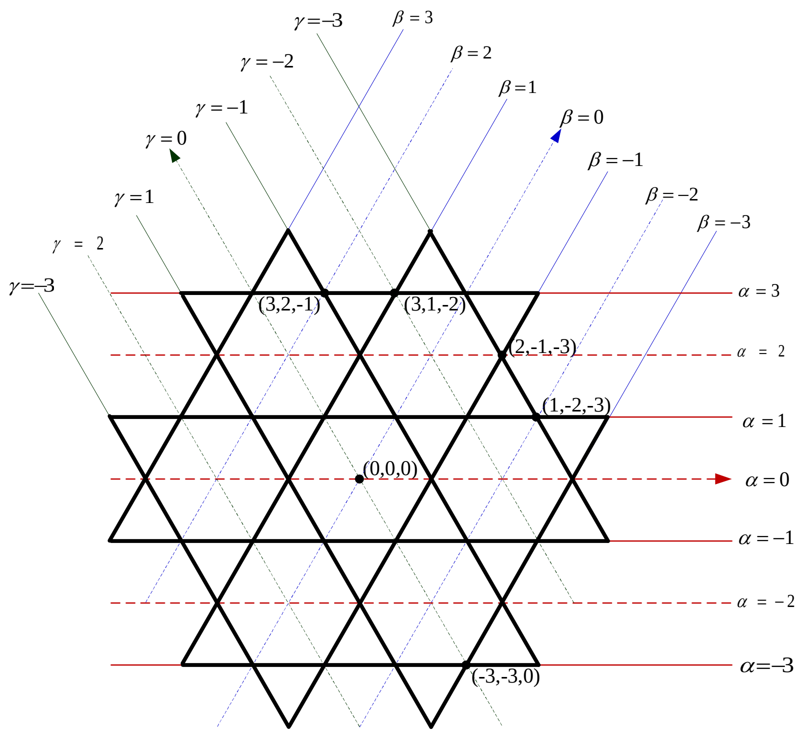

Figure 3. Coordinate System in Oxide Networks

The silicate network and Oxide network are not planar and the network cost is much more when compared to Honeycomb Torus network.

In 2006 Tomaz Dobravec et al., [13] studied the properties of circulant networks (Figure 4.) The circulant network is not planar and the network cost is much more when compared to Honeycomb Torus network.

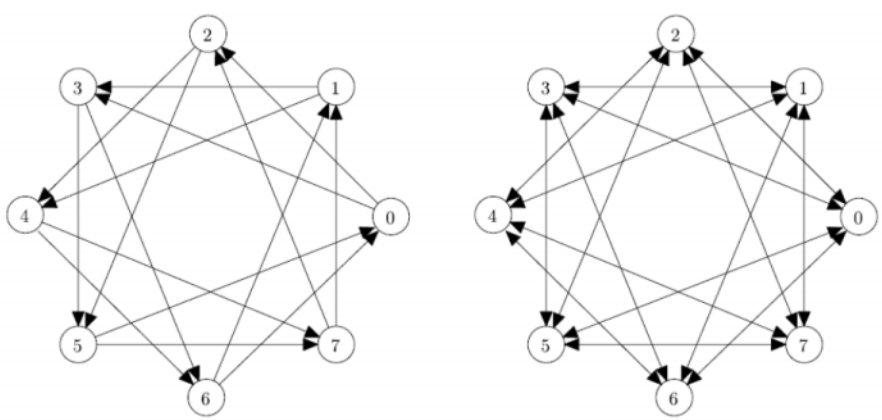

Figure 4. Circulant Network

In 2008 Paul Manuel et al., [1] studied the properties of hex derived networks. Two hex derived structures are introduced using the honeycomb network HC(n) and hexagonal network HX(n) (as shown in Figure 5).

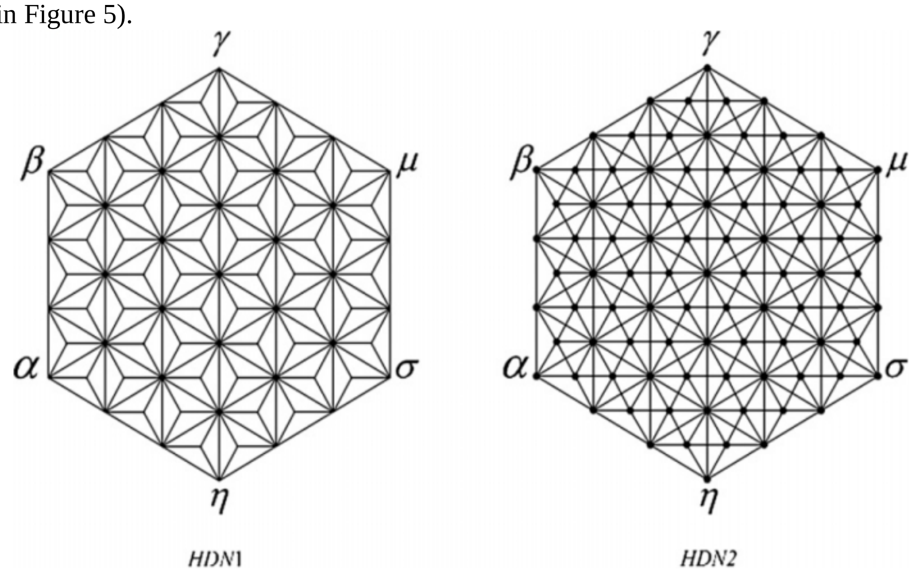

Figure 5. Hex Derived Network

The vertex corresponding to each face (a triangle) of HX(n) is placed in the face itself. Then the vertex is joined to the three vertices of the triangle. The resulting graph is a planar graph and it is called HDN1. This graph has 9n2 − 15n + 7 vertices and 27n2 − 51n + 24 edges. The diameter is 2n− 2. The second architecture is obtained from the union of HX(n) and its bounded dual HC(n − 1) by joining each honeycomb vertex with the three vertices of the corresponding face of HX(n). The resulting graph is non-planar and it is called HDN2. This graph has 9n2 −15n+7 vertices and 36n2 −72n+ 36 edges. The diameter is 2n−2. These two architectures HDN1 and HDN2 (as shown in Figure 5(a) and 5(b)) have a few advantages over the hexagonal and honeycomb networks. The vertex-edge ratio of HDN1 and HDN2 are the same as that of hexagonal and honeycomb networks.

The hex derived network cost is much more when compared to Honeycomb Torus network.In 2003 Fabian Garcia et al., [14] studied the properties of three dimensional hexagonal network

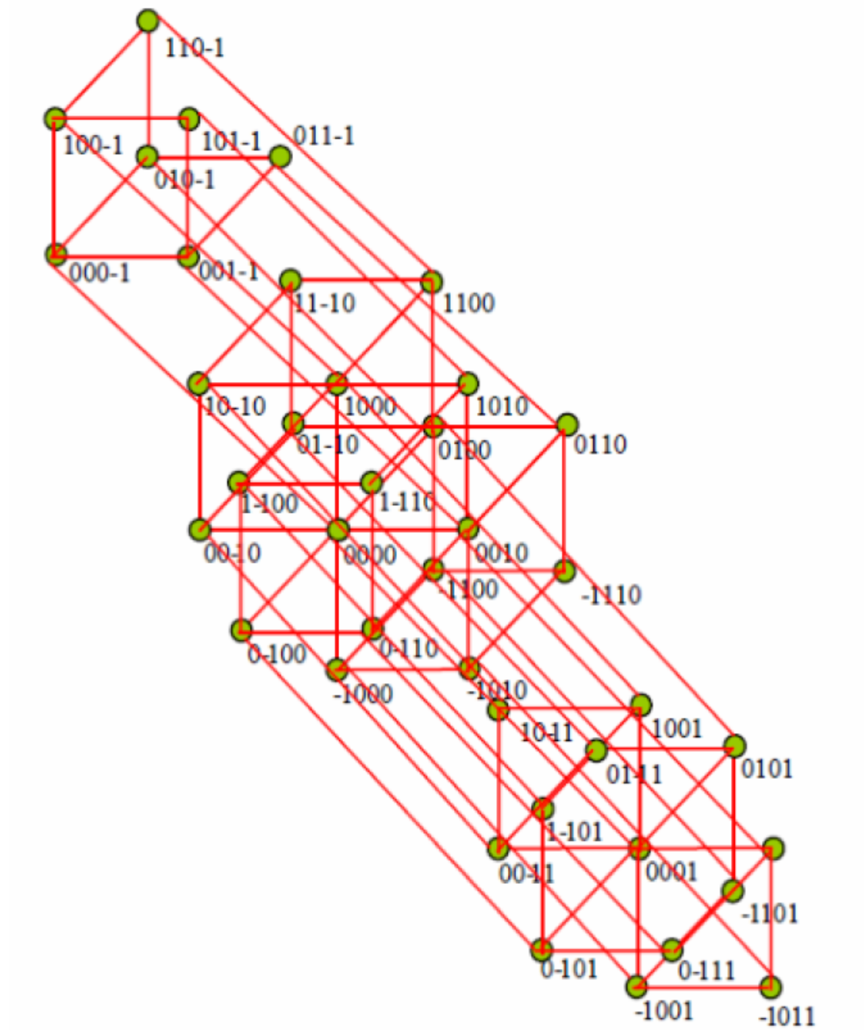

Figure 6. Three Dimensional Hexagonal Network

The three dimensional hexagonal network is not planar and the network cost is much more when compared to Honeycomb Torus network.

3. SPIDERGON NETWORK

The Spidergon network can be used for interconnecting the nodes which are present in fixed infrastructure. In this network, nodes represent routers and the topology represents the interconnection between the routers and intermediate nodes. The Spidergon topology is obtained by connecting an even number of nodes by unidirectional links to the adjacent nodes either only in clockwise or only in counter-clockwise direction plus a cross connection for each pair of nodes. Each communication link is shared by path in order to avoid deadlock.

The important characteristics of the Spidergon topology are good network diameter, low node degree, vertex symmetry and a simple routing scheme [5]. This network is used to build homogeneous building blocks in which same routers are used to connect the entire network [5].

The Spidergon topology is a variation of the ring topology and cyclic resource dependency may easily lead to deadlock situations. To handle the deadlock in the Spidergon each physical link is shared by at least two virtual channels. One channel is used only as an escape channel. An escape channel is typically adopted to avoid deadlock by preventing cyclic dependency on the access to the network resources, not to increase the performance. A message which is allowed to take the escape channels may take non-escape channels as long as it has not entered any escape channels. Once a message enters any escape channels it must take only escape channels in further transitions.

The Spidergon network has degree 3 and the diameter is p/4, where p represents the number of nodes.Figure 7, illustrates the structure of Spidergon network.

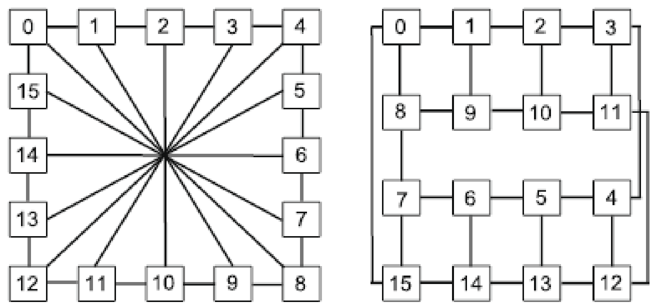

Figure 7. Spidergon network

4. HONEYCOMB TORUS NETWORK

The Honeycomb Torus network can be used for interconnecting a particular pair of nodes with wraparound edges for fixed infrastructure. In this network, nodes represent processors and the topology represents the interconnection between processors. The Honeycomb Torus topology is obtained by joining pairs of nodes of degree two of the honeycomb mesh [3]. The nodes which are mirror symmetric with respect to three lines, passing through the center of hexagonal mesh, and normal to each of three edge orientations are selected for wrapping around with edges [3]. It is observed that such wraparound edges form new hexagons.

The important characteristics of the Honeycomb Torus topology are good edge and vertex symmetry [3].

The Honeycomb Torus network has degree 3 and the diameter is $0.81\sqrt{p}$ [3], where p represents the number of nodes. Figure 8, illustrates the structure of Honeycomb Torus network.

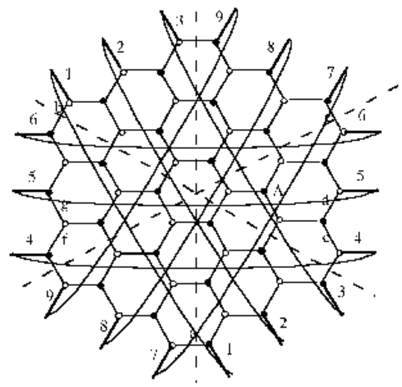

Figure 8. Honeycomb Torus network

5. AREA PLANNING

Cellular communications have experienced an explosive growth recently. To accommodate more subscribers, the size of cells must be reduced to make more efficient use of the limited frequency spectrum. This in turn, increases the difficulty level of location management. Cellular networks are commonly designed as hexagonal networks, where nodes serve as base stations to which mobile users must connect to make or receive phone calls. Hence base stations are planned in such a way that they serve all users that are located inside a hexagon centered at that base station [6]. The general problem in wireless communication is to optimize bandwidth utilization while providing better quality of service. This paper gives an idea for selecting the proper structure for a particular network with respect to network cost, which can be adopted while planning to install base stations.

6. COMPARISON OF NETWORKS

The network cost of the Spidergon network and Honeycomb Torus network are compared with respect to the number of nodes. Table 3 shows the network cost calculation for Spidergon network and Honeycomb Torus network.

Table 3. Network Cost of Spidergon Network and Honeycomb Torus Network

Network	**Degree**	**Diameter**	**Cost**
Spidergon	3	p/4	3p/4
Honeycomb Torus	3	$0.81\sqrt{p}$	$2.45\sqrt{p}$

Table 4 and Figure 9 show the network cost calculation with respect to number of nodes. It is observed that Spidergon network has slightly lower network cost (than Honeycomb Torus network) when the number of node is ≤ 10. If the number of node is increased, then Honeycomb Torus network is the best choice.

Table 4. Comparison of Network Cost based on number of nodes for Spidergon Network and Honeycomb Torus Network

Spidergon Network				Honeycomb Torus Network			
No. of nodes	**Degree**	**Diameter**	**Cost**	**No. of nodes**	**Degree**	**Diameter**	**Cost**
10	3	2.5	7.5	10	3	2.56	7.68
50	3	12.5	37.5	50	3	5.72	17.18
100	3	25	75	100	3	8.1	24.3

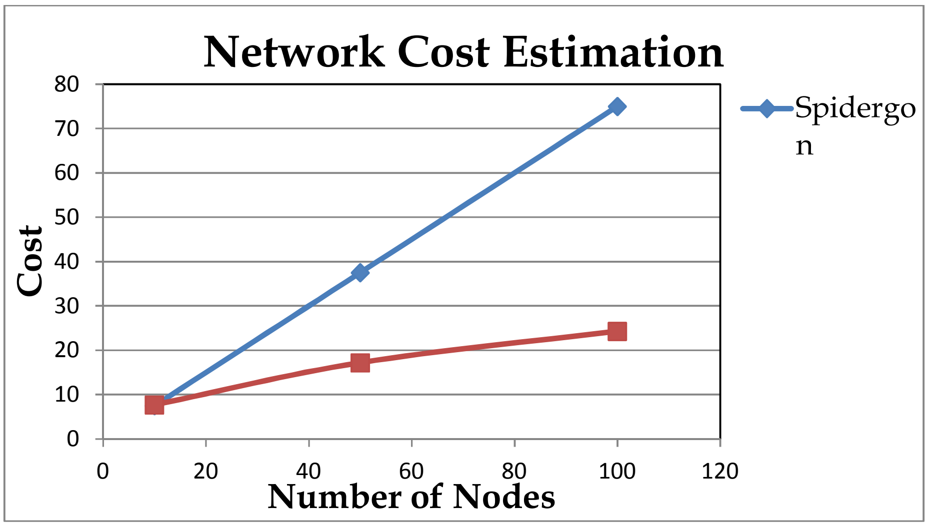

Figure 9. Network Cost Estimation

7. Conclusion

In general the Honeycomb Torus network may be having lower network cost, but the networks which are having smaller number of nodes (if number of nodes is ≤ 10) the network cost is less for Spidergon networks. The Spidergon network and Honeycomb Torus network can be used to overcome the problems in handling the user density patterns, utilizing the available bandwidth effectively and improvising the efficiency. As a future enhancement the network cost analysis can be estimated for silicate network [12], circulant network [13], honeycomb network [15], hex derived network [1] and higher dimensional honeycomb network [14] with planar structure. As industrialist prefers planar graphs, the network cost estimation of planar graphs becomes vital.

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