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SOCIAL NETWORK ANALYSIS USING THE HAMILTONIAN CIRCUIT (HC) IN A NETWORK SOCIETY

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Abstract

The Hamiltonian Circuit (HC), in contrast to the Eulerian Circuit, which only touches the edges, is of utmost importance in any social networking analysis (SNA) in a network society (NS). There haven't been any attempts to date to explore the HC and EDHC with relation to the laws of Sarnoff, Metcalfe, and Reed in the theory of networking in general and social networking in particular. One may wonder why they did not try to incorporate any circuit or HC idea into their laws of SNA. This article is an attempt to explore Circuit, HC, EDHC, and Time Complexity in Sarnoff, Metcalfe, and Reeds laws for its optimization in SNA in an NS in the hopes of closing this gap. Despite not including the concept of a circuit in their laws, it is interesting to notice that the rules of Sarnoff, Metcalfe, and Reed imply "even number of nodes" in their networking. The effectiveness of "odd numbers of nodes" versus "even numbers of nodes" in providing HC will be further investigated and demonstrated analytically. Edge disjoints of the HC-EDHC and "Time Complexity" of the three laws stated above will be investigated as a result. The SNA in NS for its optimization in social media or related applications through interaction of nodes and edges with HC, EDHC, and Time Complexity is the paper's main application.

Three sections make up the paper. The section discusses the Sarnoff, Metcalfe, and Reeds laws after a brief introduction. In today's networked society, these regulations are pertinent to social media. The usage of odd and even numbers by the HC in regard to the three laws described above is highlighted in the second part. The conclusion of Even numbers of HC for social networking on social media is the final section. Four goals can be summed up as the paper's purpose: (a) HC, (b) EDHC, (c) the appropriate algorithm, and (d) the time complexity for the SNA optimization for social media or comparable applications in a network society.

Keywords: Path; Hamiltonian Path; Edge disjoint HC; Reed; Metcalfe; Sarnoff; Node; Odd Number; Even Number; Social Media; Social Networking; Network Society.

Introduction

The writings of early sociologists are where one can find the theoretical roots of social network analysis, also known as SNA. SNA has been utilized in the literature of contemporary sociologists such as Jan van Dijk and Manuel Castells when discussing the network society. Former concept of network society, according to which the primary social structures and activities of people live their lives centered on networks of electronically processed information (Stadler, 2006). However, the latter has placed a greater emphasis on the organization and structure of information processing and interchange in preparation for the network society (van Dijk 2006: 20). According to him, the term "network society" refers to a social formation with an infrastructure of social and media networks that enables its fundamental mode or organization at four levels: (a) individual; (b) group; (c) organizational; (d) and (e) societal. He sees these four levels as enabling the fundamental mode or organization of the "network society." In the field of mathematics, the context of graph theory, we feel that this phrase is extremely important for knowing the SNA regulated by the principles of Sarnoff, Metcalf, and Reed as well as its ramifications on HC, EDHC, and Time Complexity. In addition, we believe that this term is extremely important for understanding the SNA. Not only does this indicate a shift in paradigm, but it also heralds the beginning of a new social order within the context of the network society. We are of the opinion that interaction between nodes and edges with HC, EDHC, and Time Complexity at all four levels of individual, group, organizational, and societal complexity will optimize information processing and sharing among stakeholders, as well as subsequent regulation by the laws of Sarnoff, Metcalf, and Reed.

Van Dijk (2006) noted that social network history is a part of the history of humanity. He has read The Human Web[i] by J. R. McNeill and W. H. McNeill in order to support this position. Nevertheless, social networks have existed for ever. But because of general purpose technology, social networks have become extremely important in the network society governed by the Sarnoff, Metcalfe, and Reed rules (GPT). It is understandable why Isaiah Payton (2021) has highlighted the relevance, suitability, and applicability of their laws in the global internet together with mobile phone services[ii] in his blog. He has also noted the similarity to the modern free market, where different networks can be created for the same utility and individuals are free to select the network that best serves them. Due to the groups that have developed within the networks, networks grow exponentially based on their effectiveness and adoption by nodes (consumers).[iii] It is outside the purview of this paper to critically analyse and supplement the thorough research works of Castells (2010a, 2010b, 2010c) and van Dijk (2006) within the frameworks of informational society and network society, respectively, in order to emphasise social networking in the network society as a distinct social formation. It is sufficient to note that, within the context of graph theory, HC, EDHC, and Time Complexity offer excellent insights on SNA as both a paradigm shift and the start of a new age of social formation, which are our primary concerns in this research. One could ask, "Why are Circuit, HC, and EDHC required for social networking in social media?" as a basic question. One plausible explanation is that "Odd Number" makes it possible to optimise any social networking site. The Circuit, HC, and EDHC have not, however, been taken into account by any of the three legislation. As a result, these laws are not optimised. According to our reasoning, the three components of any social networking that we can optimize—Circuit, HC, and EDHC—are not only extremely important but also essential. The following section provides a logical proof of this claim.[iv]

II: Social Networking Optimization by Circuit, HC, and EDHC

The following definitions and explanations apply to all symbols and terms used in this article.

2.1 Regular Graph

If all of a graph's vertices have equal angles, the graph is considered to be regular.

2.2 Complete Graph (K_n)

If every node in a graph is next to every other node, the graph is said to be complete. Where K_n is the entire n-vertex graph with (n-1) regularities.

2.3 Circuit

Any path in the graph that starts and finishes at the same vertex is referred to as a circuit. There are two distinct types of circuits: Hamiltonian circuits, named after William Rowan Hamilton(1805 to 1865), and Eulerian circuits, named after Leonard Euler (1707–1783).

2.4 Hamiltonian Path (HP) and Hamiltonian Circuit (HC)

Any path that passes through each vertex of a graph at least once is said to be a Hamilton Path. A Hamilton Path that starts and finishes at the same vertex is referred to as a Hamilton Circuit.

2.5 Edge Disjoints (EDHC)

A Hamiltonian cycle is one that includes each vertex of a graph G. If two Hamiltonian cycles of a graph do not share any edges, they are said to be edge-disjoint.

2.6 Vertex-transitive

If an automorphism T exists such that T (u) = v for any two vertices u, v ∈ V (G), then the graph G is said to be vertex-transitive.

2.7 Time complexity (O)

Time complexity is the amount of time taken by an algorithm to run as a function of the length of the input. It measures the time taken to execute each statement of code in an algorithm. Generally it is symbolized by Big "O"

III: Our new Approaches

3.1 Social Network Concept of Circuits

In social networks and telecommunications, the concept of a circuit is the course taken by a message or piece of information as it travels from the sender to the recipient and back again. In the past, a complete electrical route between the sender and the receiver was necessary for telephone systems to function. Social networks and social media are based on web development and communication tools that let people interact and exchange information. The social networks are an essential component of computer networks that link people together to share information. It can include a broad range of communication tools that run on a laptop, desktop, or other similar devices. The ability to share digital films, photographs, and documents, including weblogging entries like blogging, is built into mobile devices.

People utilize online platforms known as social networks to connect with others who share their perspectives, personal interests, backgrounds, in-person ties, or professional goals. A social network is an example of an online platform. There are numerous social media networking sites, such as Facebook, WhatsApp, Twitter, and others, that can be utilized for quick messaging, the sharing or posting of opinions, and a great deal more besides. As a direct consequence of this, Table 1 of the social networking system presents the most likely quantities of HCs.

Table 1: Number of Hamiltonian Circuits

Number of vertices/ Nodes	Number of Hamilton Circuits	K_n
4	3	K_4
5	12	K_5
6	60	K_6
7	360	K_7
8	2520	K_8
9	20,160	K_9
10	181,440	K_{10}
15	43,589,145,600	K_{15}
20	60,822,550,204,416,000	K_{20}

Consider that there is a blog-graph having n numbers of vertices / nodes which are connected each and every vertices / nodes and assigned as K_n. As a hypothesis, we can calculate that the numbs of Hamiltonian Circuits (**HC**s) are $\frac{(n-1)!}{2}$, whereas the number of Edge disjoint Hamiltonian Circuit(**EDHC**) has no standard formulae yet developed. In a complete Graph there are highest number of circuits which is super set of Hamiltonian Circuit. Again, Hamiltonian Circuit is a super circuit of Edge Disjoint Hamiltonian Circuit: i.e. here C is considered as a circuit and HD is Hamiltonian Circuit, and EDHC is considered as Edge Disjoint Hamiltonian Circuit. It can be mathematically shown as follows:

$$EDHC \subseteq HC \subseteq C.$$

Hence we can say that the all edge disjoint Hamiltonian Circuit (**EDHC**) is a sub graph of Hamiltonian circuit (**HC**) and HC is a sub-Graph of C (**Circuit**). However, the converse is not true.

3.2. Theoretical Investigation

3.2.1: Theorem

For K_n(n = number of vertices) when n is odd (numbers of vertices) implies more EDHC than the even numberof vertices.

Solutions: Let us consider that $K_n = K_{2n+1} + K_{2n+2}$ for all $n \geq 1$

Case I: we consider K_{2n+1} represent the number of vertex$v = (2n + 1)$ and numbers of edges $e = (2n^2 + n)$,

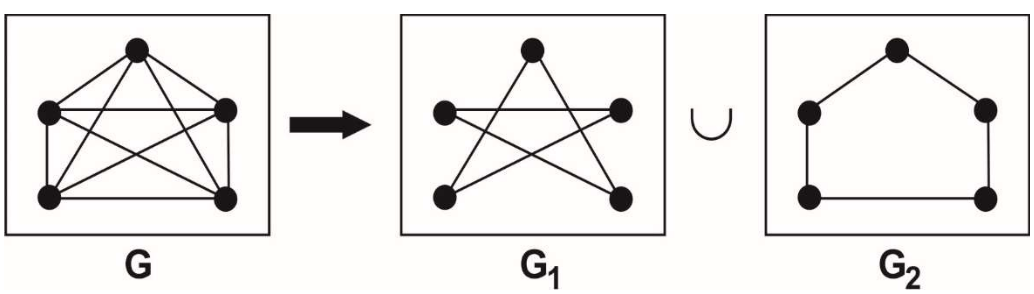
For the Graph K_{2n+1} ,for all $n \geq 2$. We have $v = 2n + 1$ and $e = 2n^2 + n$

Here we consider that for $n = 2$, then we have K_5 is complete graph of 5 vertices and 10 edges. The numbers of EDHC are as shown as G_1 and G_2

i.e. $G = G_1 \cup G_2$; $G_1 \cap G_2 = \emptyset$

Thus K_5 gives the two numbers of EDHC as shown in Graph 1.

Graph 1: EDHC Graph-I



Again, for n = 3 , we get K_7 is a complete graph of 7 vertices and 21 edges. Thus K_7 gives the three numbers of EDHC. i.e.$G = G_1 \cup G_2 \cup G_3$; $G_1 \cap G_2 \cap G_3 = \emptyset$

G_1, G_2, and G_3 as shown in Graph 2.

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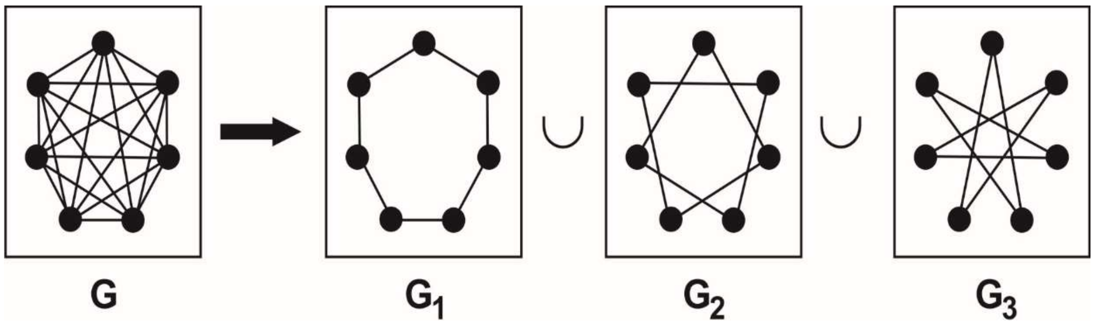
Graph 2: EDHC Graph-II



The following table 2 shows the EDHC according to the values of n.

Table 2: EDHC according to values of n

K_{2n+1}	Values of n	No of EDHC
K_3	$n = 1$	1
K_5	$n = 2$	2
K_7	$n = 3$	3
K_9	$n - 4$	4
K_{11}	$n = 5$	5
K_{13}	$n = 6$	6
K_{2n+1} for $n \geq 2$	For all n	n

Thus, we conclude that if n is odd the numbers of edge disjoint Hamiltonian circuits are n for all $n \geq 2$

Case II: Similarly for the complete graphK_{2n+2} for $n \geq 1$, we have the number of vertex$v = (2n + 2)$ and the number of edges $e = (2n^2 + 3n + 1)$.

For, $n = 2$, we get K_6 and the EDHCs are we have $G_{1,} G_2$, from the Graph K_6these are shown in Graph 3 and Table 3.

Graph 3: EDHC Graph-III

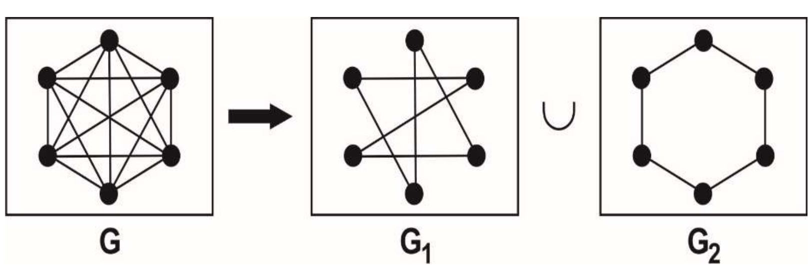


Table 3: EDHC according to values of n

K_{2n+2}	Values of n	No of EDHC
K_4	$n = 1$	1
K_6	$n = 2$	2
K_8	$n = 3$	2
K_{10}	$n = 4$	3
K_{12}	$n = 5$	4
K_{14}	$n = 6$	5
K_{2n+2} for $n \geq 3$	For all n	$n - 1$

From the case I and case II we can conclude that the numbers of EDHC gives more numbers of case-I then the Case-II. Hence a complete Graph containing odd numbers of vertices give more EDHC then the complete Graph containing even numbers of vertices. It may be noted here that there will always be HP in HDC for even number of cases.

3.3 Algorithm of Data structure to the laws of Social Network

Figure 1: Algorithm: Social Network Laws

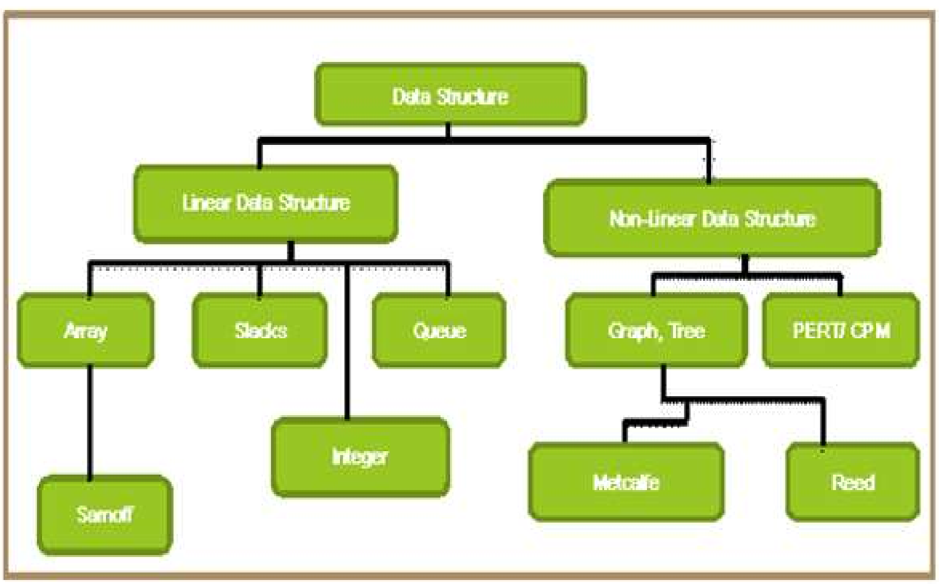
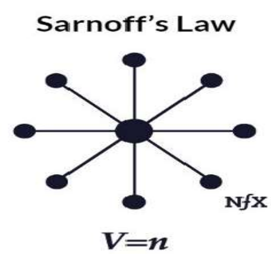


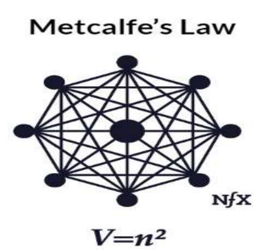
Figure 1 demonstrates that data structures can be classed in two different ways, which are referred to as linear data structures and non-linear data structures respectively. The linear data structure is sometimes referred to as Array programming, Slacks programming, Queuing programming, and Integers programming, amongst other names. The Sarnoff law is a sub-division of array data structure that provides a one-to-one linear foundation. It is a part of linear data structure, which is itself a subdivision of array data structure. It is also possible to categorize the non-linear data structure as a graph, a tree, a project evaluation and research technique (PERT), a critical management path (CPM), and many more ways.**Metcalfe** and **Reed's** laws are the part of the Graph and Tree, which is a part of non-linear data structure.Social networking laws appear to be from simple to complex and subsequently, from complex quadratic foundation to exponential foundation. Metcalfe law therefore, conveys quadratic formation and Reed law conveys exponential formations which are discussed in the following derivation of Time complexity in Graph-4.

Graph 4: Graphical Representation of Social Network

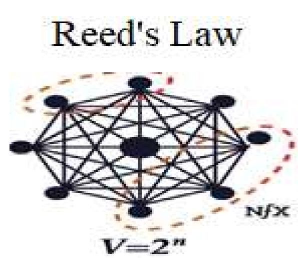
Sarnoff:

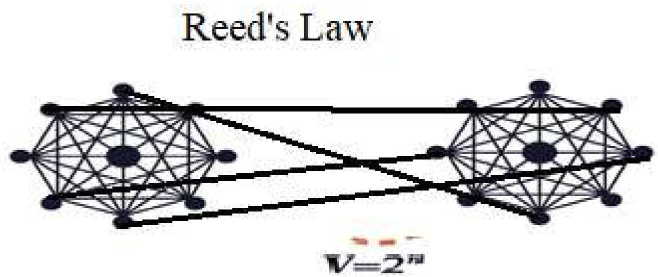


Metcalfe:



Reed:





IV: Derivations of Time complexity of O (n), O (n^2) & O (2^n) from the Laws of Social Network Theory

Assuming that time complexity arose from the **Network users**i.e. earlier the time complexity was linear when **Sarnoff** had developed one to one mapping foundation: a linear structure, in which data (elements) are arranged in a linear order, where, each and every element is attached to its preceding element as well as adjacent next one. Whenever, the number of users expanded in the form of a tree of a graph then linear time complexity has improved to Quadratic time complexity which has been explained in the law of **Metcalfe**. Finally, **Reed** has described the time complexity as an increase by exponential, non-linear structure in which data elements are attached in hierarchical order.

4.1. Sarnoff: [Linear time – O (n)]

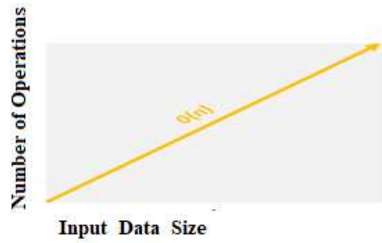
Sarnoff made the observation that the value of his network appeared to increase in direct proportion to the size of the network. Specifically, the value of his network looked to increase in a manner that was proportional to n, where n is the total number of users on the network.

When the amount of time it takes to perform an algorithm grows proportionally with the size of the input, we say that the algorithm has a linear temporal complexity. When the function includes validating all of the values in the input data, the time complexity of the function is of the order O (n): i.e., in terms of mathematics, this expression can be written as:

$1 + 1 + 1 + \cdots .. n = \sum n = O(n)$ and $O(n)$is the time complexity.

One has encountered a problem with linear time complexity, also known as O(n), when the time complexity develops in direct proportion to the amount of the input. The number of operations necessary to process the input will equal "n" for algorithms with this time complexity. This indicates that the method takes a proportionally greater amount of time to finish running as the input grows, as seen in Graph-5.

Graph 5: Sarnoff's Time Complexity



4.2. Metcalfe: [Quadratic time – O (n^2)]

According to Metcalfe's law, the value of a communications network is proportional to the square of the number of users who are connected to the system (n^2). Metcalfe's Law can be clearly demonstrated through the use of a phone network as an example.

It is claimed that an algorithm has a non-linear time complexity when the amount of time it takes to run the method grows in a manner that is not linear (n^2) with the length of the input. In most cases, nested loops fall under this time complexity order, which states that the time required to complete one loop is O(n), and if the function comprises a loop within a loop, then the time required to complete the function is O(n).

$$1 + 2 + 3 + \cdots \ldots \ldots .. + n = \text{ AP Series} = \sum \frac{n(n-1)}{2} = \sum \frac{n^2}{2} - \sum \frac{n}{2}$$

$$= \frac{1}{2}[n^2 - n] = O(n) \times O(n) - \text{neglecting the lower degree pert} = O(n^2).$$

The amount of time it takes for these kinds of algorithms to execute increases in a manner that is precisely proportional to the square of the quantity of the input (so it's similar to linear, but squared).

As illustrated in Graph-6, it is best to avoid using algorithms with quadratic time complexity in almost all cases, but especially when working with huge data sets, because they require a significant amount of time to carry out..

Graph 6: Metcalfe’s Time Complexity

4.3 Reed: [Exponential Time- O (2^n)]

Social networking users function $f(n) = 2^n$ created by David Reed[v], states that the effectiveness of large networks (and social networks theories in particular) can scale exponentially with the size and social importance of the network. In other words, Reed suggests that every new person on a network doubles its value Time (2^n).

$$2^0 + 2^1 + 2^2 + \cdots .. + 2^n = \text{GP Series} = \sum \frac{2^0(2^n-1)}{2-1} = \sum \frac{1(2^n-1)}{1} = \sum 2^n - \sum 1 = O(2^n) -$$
neglecting the lower degree part $= O(2^n)$.

In this type of method, which has a non-linear data structure and an exponential time complexity, the growth rate doubles with each addition to the input (n), and the algorithm typically iterates through all subsets of the input components. When an input unit goes up by a factor of two and a half, the number of operations that are carried out automatically goes up by a factor of four.

These kinds of algorithms are typically put to use in circumstances in which the system does not know all that much about the optimum solution, as well as for each and every potential combination or permutation that may be applied to the data, as Graph-7 demonstrates.

Graph 7: Reed's Time Complexity

V: Conclusions

We have claimed that none of the three laws—Sarnoff, Metcalfe, and Reed—took the idea of "circuit" into account for the theoretical analysis of their SNA in a network society in order to optimise networking. Despite this, the ramifications of their rules are on "even number of nodes," which is not the SNA in a network society's best interest. Mathematically, we have demonstrated that "odd numbers of nodes" produce more useful HC than "even numbers of nodes." Additionally, we have tried Edge disjoints (HC-EDHC) and looked at the Time Complexity of the three aforementioned rules. The results of our study indicate that circuit, HC, and EDHC enable network system optimization for any social media or comparable social networking applications in a network society. Finally, we firmly believe that social networking optimization in particular and networking optimization in general cannot be achieved without the concept of circuit. However, all of the law's proponents ignored mathematical rigour in favour of the technological dimension, which limited their laws' potential for optimization despite their latent promise for social networking in a network society.

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Endnotes

1. World history has been described in detail in five worldwide webs by McNeill & McNeill. According to van Dijk, all webs combine cooperation and competition, (a) social collaboration has generally increased throughout history—both voluntarily and forcibly—driven by the realities of social rivalry, and (b) human webs have a tendency to expand.
2. It is important to note that without GPT (General Purpose Technology), these advancements would not have been possible. For more information on GPT and its influence on societal development (both economic and social), see Basu and Fernald (2008), Bresnahan and Trajtenberg (1995), Helpman (1998), and Youtie et al. (2021).
3. According to Payton (2021), none of these rules take into account "trust and transparency" (our emphasis added) when analysing the network and its impacts on the overall ecosystem. The integrity of the central or primary network, from which the entire network expanded, was practically never questioned. As a result, Sergey Nazarov came up with what Payton refers to as DeOr's Law (Decentralized Oracle Law). However, the laws of Sarnoff, Metcalfe, and Reed are the only ones we are concerned with in this study. This is also the paper's limitation.
4. Before moving on, it should be noted that a face is a single flat surface, an edge is a line segment connecting two vertices, and a vertex is a corner. Furthermore, Hamilton contributed to Vertex in 1800 and Leonhard Euler contributed to Edges and Vertices in 1736.
5. In 1952, David Patrick Reed had conceived social networking users function. He graduated from the Massachusetts Institute of Technology in the United States with a degree in computer science. He was initially involved in the creation of the TCP/IP internet protocol. He is well known for Reed's law, which states that the usefulness of huge networks can increase exponentially with network size. It holds true for networks with clusters, whose value grows exponentially. According to this, social networks, in particular, can be extremely useful on a

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wide scale. According to the logic given, where N is the total number of participants, there are N possible subgroups of network users. In accordance with Metcalfe's rule, this increases considerably more quickly than the total number of participants, N, or the total number of potential pair connections, N(N 1)/2.