

A new method for complexity determination to be used in new hyper-hybrid AD HOC cloud computing

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Abstract. The paper presents a new method for complexity determination to be used in new hyper-hybrid AD HOC cloud computing. A large body of research has been devoted to identifying the complexity of network structures. The study of complex networks is a young and active area of scientific research inspired largely by the empirical study of real-world networks, such as computer and social networks. The new method enables quantifying the complexity of a new hyper hybrid AD HOC cloud network based on presenting the network nodes in the Cartesian coordinates, converting to polar coordinates, and calculating the fractal dimension. The results suggest that the method can be used to determine the complexity for any type of the network.

Keywords: complexity, cloud computing, *AD HOC* network, hyper hybrid network

Nova metoda za določitev kompleksnosti in njena uporaba v novem hiper hibridnem AD HOC računalništvu v oblaku

V prispevku predstavljamo novo metodo za določitev kompleksnosti in njeno uporabo v novem hiper-hibridnem AD HOC oblaknem računalništvu. Velik raziskav je bilo namenjeno ugotavljanju kompleksnosti struktur v omrežjih. Študija kompleksnih mrež je mlada in aktivno področje znanstvenih raziskav v veliki meri zgledeje po empiričnih raziskavah v realnem svetu omrežij, kot so računalniška omrežja in socialna omrežja. V tem prispevku bomo predstavili novo metodo za računanje kompleksnosti novega hiper hibrida AD HOC omrežja, ki temelji na predstavitvi vozlišča omrežja v kartezičnih koordinatah, pretvorbo v polarne koordinate in izračun fraktalne dimenzije. Naši rezultati kažejo, da je ta pristop mogoče uporabiti za določitev kompleksnosti za vsak tip omrežja.

1 INTRODUCTION

In computer networking, an *AD HOC* network [1-4] refers to a network connection established for a single session and does not require a router or a wireless base station. Many ad hoc networks are local area networks where computers or other devices are enabled to send data directly to one another rather than going through a centralized access point. A wireless network transmits from computer to computer. Instead of using a central base station (access point) to which all computers must communicate, this peer-to-peer mode of operation can greatly extend the distance of the wireless network. To gain access to the Internet, one of the computers can be connected via wire or wireless to an ISP. Basically, an ad hoc network is a temporary network connection created for a specific purpose, such as transferring data from one computer to another. Networks are a

ubiquitous way to represent complex systems, including those in the social and economic sciences. Understanding complexity and broad systems-level frameworks in the life, physical and social sciences have turned, in recent decades, to issues of network dynamics. The growth of the World Wide Web, staggering advances in computing the power and diminishing the computational complexity of network algorithms, and demonstrations of the robustness and ubiquity of networks fitting small-world models have helped to spark much of the recent cross-disciplinary explosion in network analysis and modelling.

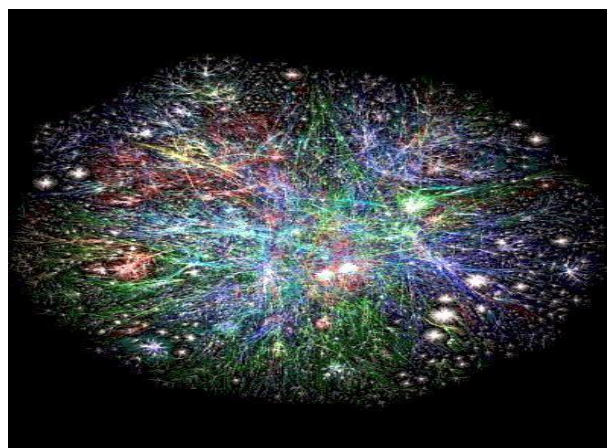


Figure 1. Internet, the global communication network

It has been shown that many real complex networks [5-7] share distinctive characteristic properties that differ in many ways from the random and regular networks.

Fig. 1 presents a network of the global communication network, namely internet. The size and nature of data collected on an *AD HOC* network and wireless have led to a rapid growth of interest in the graph theory [8-10] and modern techniques for describing, characterizing and comparing networks. Traditionally, complex networks have been described with the random graph theory of Erdos and Renyi, for which each pair of nodes is connected at random with probability (p). A graph is a bunch of vertices and edges (also known as nodes and arcs). Each edge joins two vertices. That's all a graph is. A hybrid network [11] is a network that contains two or more communication standards in one network design. A hybrid network can also refer to a network design that combines two or more types of basic physical topologies, such as multiple star topologies connected by a bus topology. We are looking for a perfect network solution, utilizing the advantages of the public and private networks and the one that uses the advantages of both and VPN. A hyper hybrid network presents a new method and solution to this problem. Fig. 2 presents a hybrid network.

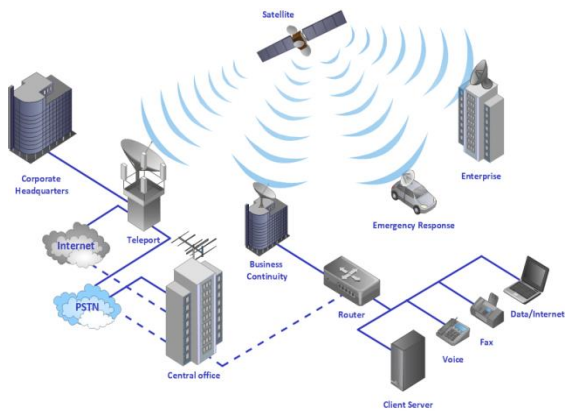


Figure 2. Hybrid network

In this paper we introduce a new method for quantifying the complexity of a new hyper hybrid *AD HOC* cloud computing [12-13] network based on presenting the nodes of the network in the Cartesian coordinates, converting to polar coordinates, and using fractal geometry. In the fractal geometry [14-15], the fractal dimension, D , is a statistical quantity that gives an indication of how completely a fractal appears to fill the space as one zooms down to finer and finer scales. Also, the key of the fractal geometry is the fractal dimension which describes the complexity of self-similar objects. An object is self-similar if it is exactly or approximately similar to a part of itself, i.e it looks the same on all length scales. As self-similarity is a typical property of fractals, to unravel the self-similar property of some networks, we use the methods introduced to investigate fractals.

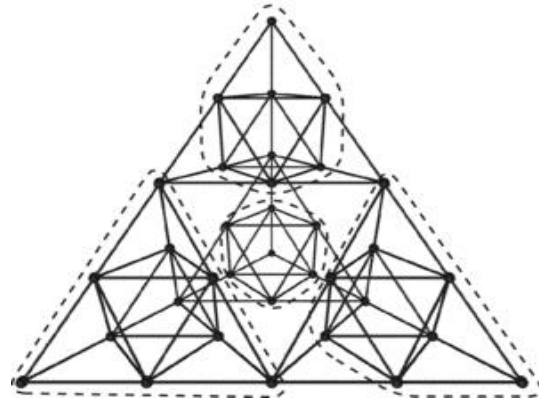


Figure 3. Self-similar network

Our results suggest that this approach can be used to determine the complexity for any type of the network. Our most striking finding is that all networks have complexity $D \sim 2$.

1.1 Open Problems and Challenges

In the today's world of information science, some of the most popular, fascinating and useful structures are the *AD HOC* networks. However they have also given rise to many open problems. Some of them are:

Problem 1. The characteristics of large *AD HOC* networks vary if examined at different magnifications. The Questions is: Can we find a relationship between magnification of large networks and their topological properties? What is the impact of a small network on a large one? And can we gain an insight into the network properties by researching small networks inside the large ones?

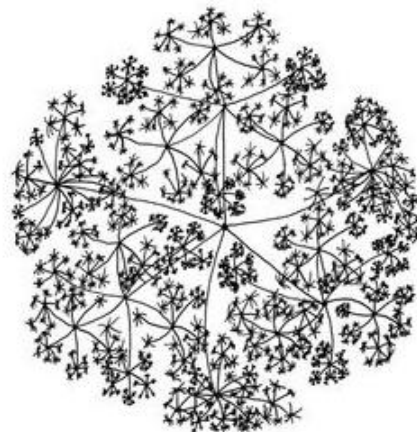


Figure 4. Fractal graph

Problem 2. An *AD HOC* network of spacecraft around and in transit between the Earth and Mars. Direct communication between the Earth and Mars can be strongly disturbed and even blocked by the Sun for weeks at a time, cutting off any future human mission to the Red Planet. The Questions is: How to ensure a reliable radio communication even when the line up at opposite sides of the Sun, which then blocks any signal between mission controllers on the Earth and astronauts on the red surface.

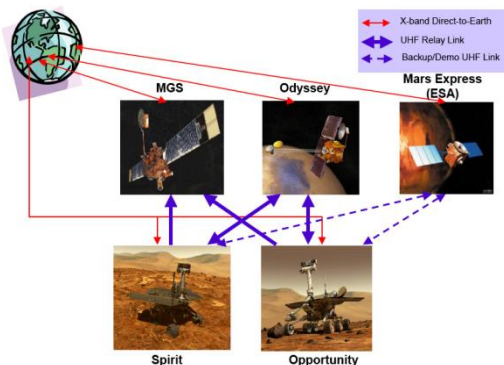


Figure 5. MER Telecommunication Architecture

Problem 3. Security is a critical issue of the *AD HOC* networks that is still a largely unexplored area. Traditional methods of protecting the data with cryptographic methods face a challenging task of key distribution and refresh. The main objectives of the proposed research are to develop secure authentication and key management protocols specific to the needs of the *AD HOC* networks and to design highly-efficient hardware architectures of the proposed protocols.



Figure 6. Wireless AD HOC Network Characteristics

Problem 4. Without a fixed infrastructure, the *AD HOC* networks have to rely on portable, limited power sources. A node in an *AD HOC* network has to relay messages for other nodes in the same network. The issue of energy-efficiency therefore becomes one of the most important problems in the *AD HOC* networks.

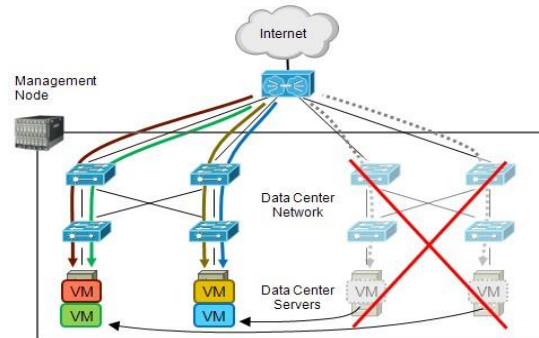


Fig.

Figure 7. Energy-Efficient Data Center Networking: Virtual Machine and Network Flow Consolidation

Problem 5. A wireless mesh of rooftop-mounted *AD HOC* routers; an *AD HOC* network of cars for instant traffic and other information.



Figure 8. Mesh Network

Therefore, the proposed studies for all open problems would involve novel approaches to the *AD HOC* network modeling and could contribute to predicting the behavior of the *AD HOC* networks in future. All these problems can be solved with a mathematical tool; the graph theory. Representing a problem as a graph can make a problem much simple. A graph is a way of specifying relationships among a collection of items. In mathematics and computer science, the graph theory is a study of graphs which are mathematical structures used to model pair-wise relations between objects. A graph consists of a set of objects, called nodes, with certain pairs of these objects connected by links called edges. Nodes represent computing hosts, and there is an edge joining two nodes in this picture if there is a direct communication link between them. Graphs are useful because they serve as mathematical models of network structures. The Graph theory is a suitable play ground for exploration of proof techniques in discrete mathematics, and its results have applications in many areas such as computing, social, and natural sciences.

Network analysis has been developing and flourishing for several decades. Network analysis is popular in every type of academic social science, AD DOV network, applied social science (such as marketing), studies of nonhuman social life, branches of mathematics, computer science, and even physics.

2 METHODS

In this paper we introduce a new method for quantifying the network complexity based on presenting the nodes of the network in the Cartesian coordinates, converting to polar coordinates, and calculating the fractal dimension.

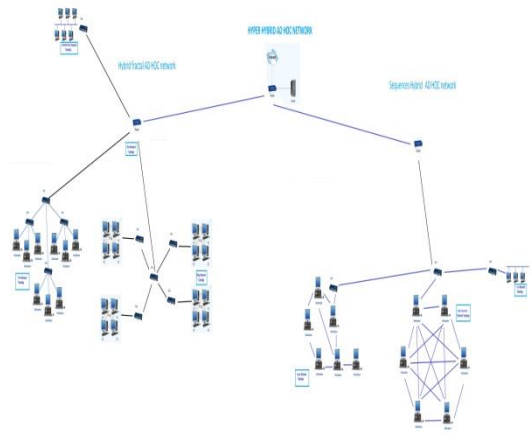


Figure 9. Hyper hybrid AD HOC network

First of all, all nodes of the network are presented in the Cartesian coordinate system. Also, coordinates (x,y) of every node of the network (Step 1) are determined.

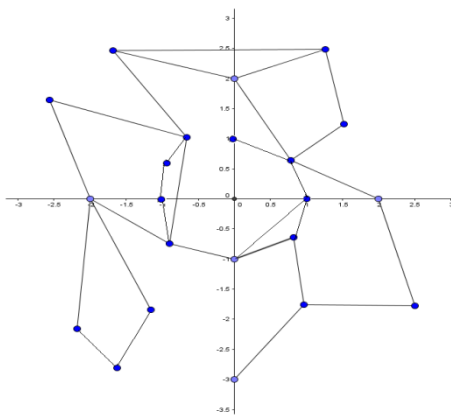


Figure 10. Step 1

In Step 2, the nodes of the graph are transformed into a polar coordinate system (Step 2). This means that all nodes have two coordinates (r, Φ). So, to convert from the Cartesian coordinates (x,y) to the Polar coordinates (r, Φ):

$$r = \sqrt{x^2 + y^2}$$

$$\tan \Phi = \frac{y}{x}$$

$$\Phi = \arctan\left(\frac{y}{x}\right)$$

Also, transformation of the nodes (x,y) into (r, Φ) can be described:

$$P(r, \Phi) = P(\sqrt{x^2 + y^2}, \arctan(\frac{y}{x}))$$

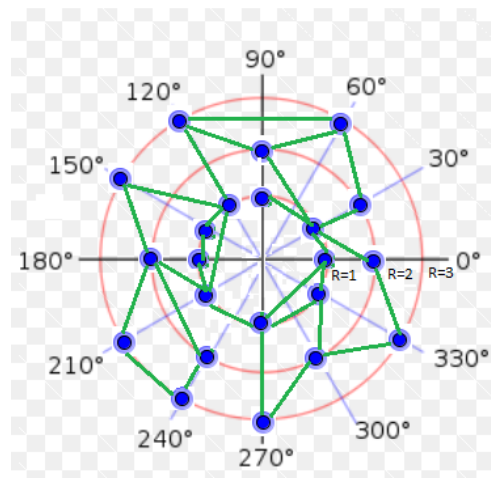


Figure 11. Step 2

Also, in the polar coordinate system, the points (nodes) are presented as $T_i(r_i, n_i)$. For all r_i , the number of nodes is denoted as n_i for all i . All points $T_i(r_i, n_i)$ represent linear graph $I(r, n)$.

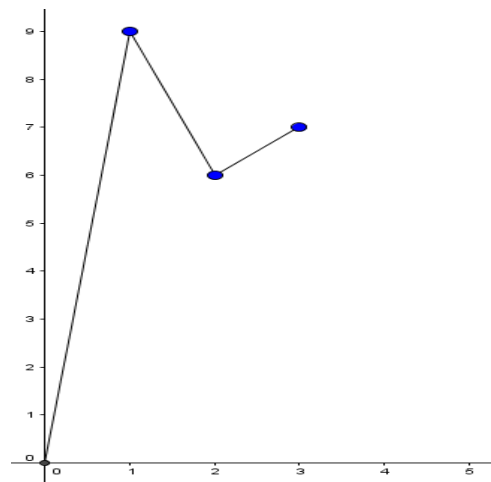


Figure 12. Linear graph $I(r, n)$ of the network

A random process is statistically evaluated using Hurst parameter H [16] or by determining the distribution function. Hurst parameter H as a self-similarity criterion

can not be accurately calculated; it can only be estimated. There are several different methods [17] to produce estimates of parameter H , which together more or less deviate. In doing so, there is no criterion to determine which method gives us the best result.

We use the R/S method for estimating Hurst exponent H . The R/S method which adjusts the rescaled range method or the scale is also a graphic method based on the properties of the Hurst phenomenon. The adjusted scale of the partial summation area is a time series deviation from the mean. For graph $\Gamma(r, n)$, the Hurst exponent H (Step 3) is estimated.

The rescaled range is calculated for a time series or space component,

$$X = X_1, X_2, \dots, X_n$$

as follows:

Calculate m by equation (1), calculate cumulative deviate series Z by equation (2), create range series $R(n)$ by equation (3), create standard deviation series S by equation (4), and calculate the rescaled range series (R/S) by equation (5).

(1)

$$m = \frac{1}{n} \sum_{i=1}^n X_i$$

(2)

$$Z_t = \sum_{i=1}^t (X_i - m)$$

(3)

$$R(n) = \max(Z_1, Z_2, \dots, Z_n) - \min(Z_1, Z_2, \dots, Z_n)$$

(4)

$$S = \sqrt{\frac{1}{n} \sum_{i=1}^t (X_i - m)^2}$$

(5)

$$\frac{R}{S} = \left(\frac{n}{2}\right)^H$$

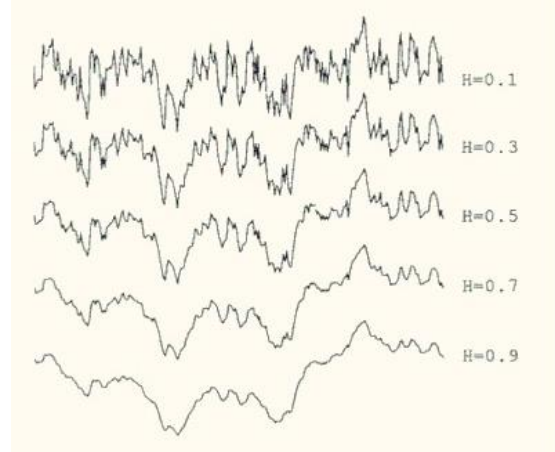


Figure 13. Step 3

Fig. 13 presents different graphs and Hurst exponent H .

Now, the fractal dimension can be calculated with equation $D=2-H$ (Step 4). Hurst exponent $H \in (0,1)$, thus the fractal dimension of complex networks, is $D \in (1,2)$.

3 RESULTS AND DISCUSSION

We present a random network with 111 nodes. This network is very complex and has fractal characteristics.

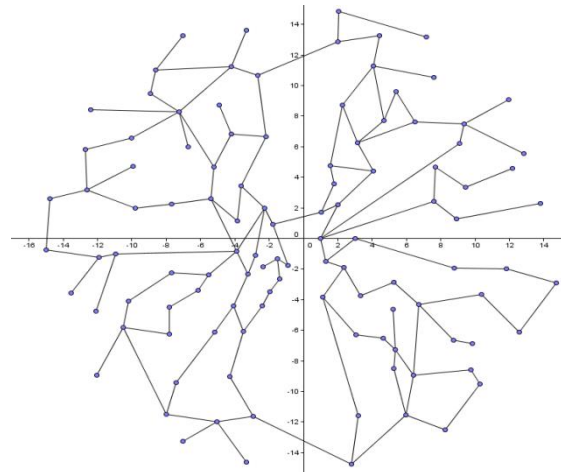


Figure 14. Random network with 111 nodes

Complexity of the presented random network is calculated with R/S method to estimate Hurst exponent H . Hurst exponent H for the network is 0.15, thus its fractal dimension is 1.85 and its complexity is 1.85. Fig. 16. presents linear graph $\Gamma(r, n)$ of the network. Also, for each r , we number n of the nodes is determined.

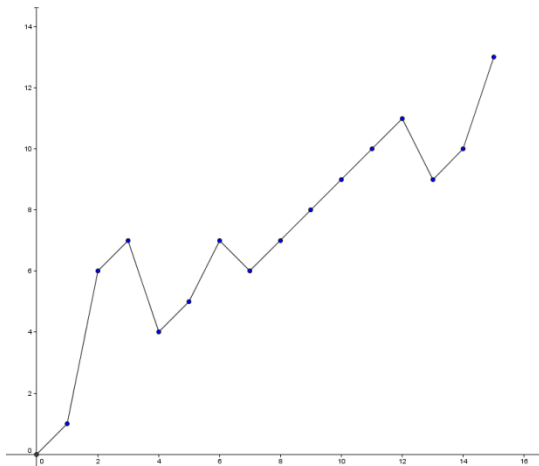


Figure 15. Linear graph $I(r, n)$ of the random network with 111 nodes

In this paper, we introduce a new method for quantifying the complexity of a new hyper hybrid *AD HOC* cloud network based on presenting the nodes of the network in the Cartesian coordinates, converting to polar coordinates, and calculating the fractal dimension.

4 CONCLUSION

In this work we present a new method for network complexity determination to be applied in cloud computing and *AD HOC* networks. Ten challenging problems are highlighted. One of them can be solved by using the presented method of the network complexity. Our results suggest that using the presented method, complexity of any network can be determined.

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