KADIR HAS UNIVERSITY

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HUB ANALYSIS OF HEALTH INFORMATION PLATFORM FROM A NETWORK SCIENCE PERSPECTIVE

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ŞEYMA ÇALIŞAN ÖZYURT

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ŞEYMA ÇALIŞAN ÖZYURT

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ŞEYMA ÇALIŞAN ÖZYURT

APPROVED BY:

Assoc. Prof. Dr. Mehmet N. Aydın (Advisor) ____________

Asst. Prof. Dr. N. Ziya Perdahçı ____________

Assoc. Prof. Dr. Cesim ERTEN ____________

APPROVAL DATE: 28/05/2015

“I, Şeyma Çalışan Özyurt, confirm that the work presented in this M.S Thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the M.S. Thesis”

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ŞEYMA ÇALIŞAN ÖZYURT

HUB ANALYSIS OF HEALTH INFORMATION PLATFORM FROM A NETWORK SCIENCE PERSPECTIVE

Abstract

Online information platforms such as social networking applications are subject to examination of the underlying interactions as a network. Managers of these platforms are often unaware what constitutes the very idea of network growth. Conventional web and social analytics metrics are not adequate to surface the intriguing interplays among individuals interacting on these platforms. Thus, the challenge for managers is to know what underlies growth of the network on these platforms. The goal of this research is to identify growth mechanisms via hubs of an online health platform from a network science perspective. In particular, it is aimed to understand characteristics of the most connected nodes, so-called "Hubs", so that hub contributions to network growth can be discerned. From a network science perspective, the research is realized by examining the time dependent graph of hubs along with their attributes, which are the role and gender attributes. The only common pattern that is observed for hub behavior over time can be best described as typical step functions or "staircase" functions. Furthermore, one of the most prominent features of hub is observed in this online information health platform, appears to be dissassortativity. That is, hubs form edges with different role or gender nodes. Actually, almost all hubs form edges in the opposite gender. Also, they prefer to form edges with different role nodes in general. This research will guide for platform managers to decide alternating product attractiveness or customer loyalty opportunities.

Key words: Network Science, Network Graph, Health Information Network, Hub Development, Degree Distribution, Dissassortativity

AĞ BİLİMİ AÇISINDAN SAĞLIK BİLGİ PLATFORMUNDA MERKEZ ÜYE ANALİZİ

Özet

Sosyal ağ uygulamaları benzeri çevrimiçi platformlar, ağın temelini oluşturan etkileşimlerin incelenmesine bağlıdır. Platform yöneticileri çoğu zaman ağın büyümesinin neye bağlı olduğunun farkında olmazlar. Geleneksel web ve sosyal analiz ölçütleri, bireyler arasındaki merak uyandıran etkileşimleri ortaya çıkarmakta yetersiz kalmaktadır. Bu nedenle, platform yöneticileri için zorlu olan, bu platformların büyümesinin altında yatan etkenleri ortaya çıkarmaktır. Bu araştırmanın amacı, çevrimiçi platformların ağ bilimi açısından incelenerek ağlardaki büyümeyi sağlayan mekanizmaları gözlemlemektir. Özellikle, "Merkez Üye / Hub" olarak adlandırılan, bağlantı derecesi merkez sınıfına girecek kadar yüksek olan platform üyelerinin belirgin özellik ve davranışlarına odaklanarak ağdaki büyümeye olan katkılarını anlayabilmek hedeflenmiştir. Ağ bilimi açısından her bir merkez üyenin rolü (doktor; diğer) ve cinsiyeti ile birlikte, zamanın bir fonksiyonu olarak (haftalık bazda) kurduğu yeni bağlantıların bağlantı-zaman grafikleri incelenerek araştırma gerçekleştirilmiştir. Merkez üyelerin zamana bağlı olarak incelenen davranışlarının gözlemlenmesi sonucu tek ortak noktalarının adım fonksiyonu ya da basmak fonksiyonu olduğu belirlenmiştir. Ayrıca, incelenen çevrimiçi sağlık bilgi platformunda gözlemlenen, merkez üyelere ait en belirgin özellik negatif ayrımcılık denilen benzer rol ve cinsiyette olmayanların iletişim kurma eğilimi olarak görülmektedir. Gözlemlenildiği kadarıyla neredeyse tüm merkez üyeler karşı cins ile iletişim kuraktadır. Ve genellikle farklı roldeki üyeler ile iletişim kurmayı devam ettirmektedirler. Bu araştırma platform yöneticileri için ürün çekiciliğinde ya da müşteri sadakati yönetiminde alternatif karar verme imkânları sunma konusunda yol gösterici olacaktır.

Anahtar Kelimeler: Ağ Bilimi, Ağ Temsili, Sağlık Bilgi Platformu, Merkez Üye, Derece Dağılımı, Negatif Ayrımcılık

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Chapter 1

Introduction

Nowadays, we are faced with increasing overall relations with friends and other agencies via technologies even though, urbanization develops rapidly, and *human* communities are concentrated in cities with close proximity. Many of us live in big cities, which is called megalopolis, and our living areas like work, school and hospital are becoming more and more crowded. This causes an increase in social relations among people. With the increase in the usage of the Internet, social relations become possible online and this type of online relations results in the increase of interest in online *networking* from day to day. Our life is surrounded by many systems from social communities to mobile phone network. The uninterrupted functioning of a social community depends on the cooperation of billions of individuals, just as the functioning of communication infrastructure which integrates billions of mobile phones to computers and satellites. Our ability to comprehend and understand what is going around us is only possible through the functioning of billions of nerves in our brain in harmony (Haykin, 2004). All these systems are called "complex systems" (Hwang et al., 2013). They have undeniable roles both in our daily lives and in science and economy. And scientifically and intellectually, problems of comprehending, defining mathematically, predicting and ultimately controlling the complex systems became one of the most challenging subjects of the twenty-first century.

This current situation, makes it even more important to understand relational networks and their impact on our lives. Actually, behind the twenty-first century's revolutionary technology, there are networks. From Google to Facebook or from CISCO to Twitter, the real power of many technology companies lies in the networks that they have (Kwak et al., 2010). To sum up, when we compare with "ordinary" scientific work, networks make possible for us to penetrate into science, technology and nature in a highly organized and complicated way. As a result, today, the common belief is that modelling and searching the complex systems are possible only through the in-depth understanding of basic underlying networks. Such studies have been done using some of the techniques from the scientific point of view. For example, by examining the whole relations of terrorist groups, a proper way to deal with them was trying to be found or some search techniques were developed using the individual network relations to find a wanted person (Ressler, 2006). The notion of network science influenced military doctrine and network-war began (Arquilla and Ronfeldt, 2001). In 2009, the USA Defense Ministry gave $ 300 million for R&D activities for network developing in the security sector.

Over the last decade, the increasing numbers of the online health networks attract both academics and practitioners. Some examples of these platforms include healthtap.com, doktorsitesi.com, doktorumonline.net, doktorburada.com. Although information sharing service on the platform seem simple among a visitor and physician in the online health network, it enables complex relations particularly since there are ten thousands of online health platform user as visitors or physicians with the interactions between visitor-visitor, physician-physician, or visitor-physician. Describing the intricate interactions of websites has attracted many scholars in different fields such as computer scientist, physics, mathematics, and management science with a common theme called complex systems, which underpins the very emerging scientific field, called network science. However, it is quite troublesome to reach convenient real-word data on scientific studies (Barabási and Frangos, 2014).

Modelling the real-world complex systems through the graphs, shows that these systems have common characteristic features making them different from random computer generated complex systems (Strogatz, 2001). Even it should be seen as a significant contribution in itself to examine the almost universally accepted scientific findings which can be grouped under headings real-world networks laws, principles and phenomena through on web sites providing interactive services. The main objective of this study is contributing to the scientific community in this regard precisely (Boccaletti et al., 2006).

Doktorsitesi.com is an online health platform, which we studied on the data of it. "www.doktorsitesi.com" is established to inform users, who may be health professionals which we called physician or other members having health problems possibly called as visitor, about public health information. For instances, it can be asked general questions to the physicians through the "My Questions" service and visitors can be sent private messages to each other through the "Connections" service. The first service provides can be able to ask public questions to physicians by the visitors, the second feature would enable visitors to ask private question or any subject only to a physician or visitor which is formed edge with them. In the preferred network structure, nodes represent members who are physician or visitor, undirected links represent the ties which are formed edges between members (Aydin and Perdahci, 2013).

We study on the year 2012 network data of the Doktorsitesi.com which constituted 2143 nodes and 5706 edges. We specified the maximum 22 nodes as hubs which is the %1 of total node number. Despite there are 5706 edges totally in the network, this one percent group of all nodes has 2798 edges which is almost the fifty percent of total edge number. So, this is interesting and encourages us to examine the hubs which we have their role and gender attributes also. We tried to understand the effects of hubs on the network growth and we analysed hub developments and hub behaviours with tie-time dependent graph in detail. We used Gephi for visualization and Excel for detailed analyse of each hub with the help of weekly tie-time graphs. We have seen hub development figures which are not similar but some "steps" are commonly occurred by hubs which we explain in results section of our study. Also, we observed the dissassortative relations as result of detailed hub behaviour analyse. These outcomes may be significant guides for platform managers informing them particularly in terms of the customer loyalty.

This study is designed as six parts. We give theoretical background in the first two chapters and experiential study is conveyed in the rest four chapters.

— Research background is given in the second chapter which examines the literature and includes the theoretical approaches of network. This chapter consists four parts as follow:

  - 2.1: This part introduces a literature review for network, network science, and graph theory view of networks, complex and social networks.
  - 2.2: This part includes some basic definitions for online social networks including properties, structure and evolution of social networks.
  - 2.3: This part includes a literature review for scale-free networks and investigates the distinction between The Bianconi- Barabási and the Barabási–Albert models.
  - 2.4: This part includes a literature review for assortative mixing and dissassortative mixing characterization of social networks.

— Chapter 3 is the part where research methodology is given in detail and explains which methodologies are used for the experimental study.

— Chapter 4 is consist of the results of the experimental study and includes 3 parts as follows:

  - 3.1: This part introduces overall analysis of hubs.
  - 3.2: This part includes hub specific analysis.
  - 3.3: This part includes comparative analysis.

— Chapter 5 is the discussion part including implications for network science and practice for online platforms.

— Chapter 6 includes conclusion for the experiential study and explains the importance of the study for network science.

Chapter 2

Research Background

2.1 Network, Network Science, Complex Networks, Social Network

In this study, we will start with a brief introduction about what is actually meant by a network. We first discuss on some basic formal concepts and notations from graph theory, together with a few fundamental properties that characterize networks.

Networks and their properties are characterized by a structure that limit or enhance their behavior. To fully understand how networks affect the properties of a system, we need to become familiar with graph theory. In its simplest form, a graph is a collection of vertices that can be connected to each other by means of edges. In particular, each edge of graph joins exactly two vertices (Van Steen, 2010).

A network is a collection of nodes or vertices, interactions between them links or edges, in the same sense a graph is an object occurred by vertices and edges (Barabási, 2015e). In network science, a network consists of nodes and links. The terms network and graph are most of the time used one for another. We discuss about a social online health network which is a social graph. So, we will use the both terminologies as synonyms of each other.

In order to have a better understanding of a complex system, a map of connection diagrams is useful tools (Barabási, 2015f). It is required for us having a map of the system's connection schema, to make clearer the behavior of a system which includes of large number elements. For instances, we need to have list of friends, friends' friends, and so on. Map inform us which friends have interaction to each other and simplifies to analyze the whole data.

The connections in the network can be directed or undirected, if the nodes have directed edges completely in a network it is called directed graph or digraph but if all edges are undirected it is called undirected graph (Barabási, 2015e). Sometimes networks can be includes both of the directed and undirected edges. In our study, we have an undirected network which is called tie network at the same time, relations have reciprocity.

In a network, the degree of a node is the number of ties or edges the node which has to other nodes. Degree is an important feature for a node that we will make use of analyzing the network hubs frequently in our study. The probability distribution of the degrees over the entire network is called degree distribution and it has a great importance in network theory. The degree distribution has taken a central role in network theory following the discovery of scale-free networks.

A scale-free network is a network whose degree distribution follows a power law which decreases as the node degree increases. That is, the fraction P (k) of nodes in the network having k connections to other nodes goes for large values of k as $P(k) \sim k^{-\gamma}$ where $2 < \gamma < 3$ typically. This means that the low-degree nodes belong to very dense sub-graphs and those sub-graphs are connected to each other through hubs (Choromański et al., 2013).

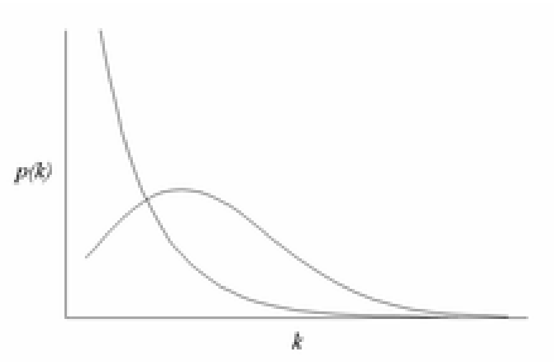


Figure 2. 1 Complex network degree distribution of random and real networks

Consider a social network in which nodes are people and links are acquaintance relationships between people. It is easy to see that people tend to form communities, i.e., small groups in which everyone knows everyone (one can think of such community as a complete graph). In addition, the members of a community also have a few acquaintance relationships to people outside that community. Some people, however, are connected to a large number of communities (e.g., celebrities, politicians). Those people may be considered the hubs responsible for the small-world phenomenon (Watts and Strogatz, 1998).

Real networks are separated from traditional assumptions of network theory. Traditionally, real networks were supposed to have a majority of nodes of about the same number of connections around an average. This is typically modeled by random graphs. But modern network research could show that the majority of nodes of real networks are very low connected, and, by contrast, there exists some nodes of very extreme connectivity (hubs). This power-law (scale-free) characteristic can be found in many real networks from biological to social networks (Hein et al., 2006). However, it turns out that power-law (scale-free) node-degree distributions are a property of only sparsely connected networks.

We see in the below chart the degree distributions of random networks and real networks (Scholz, 2015).

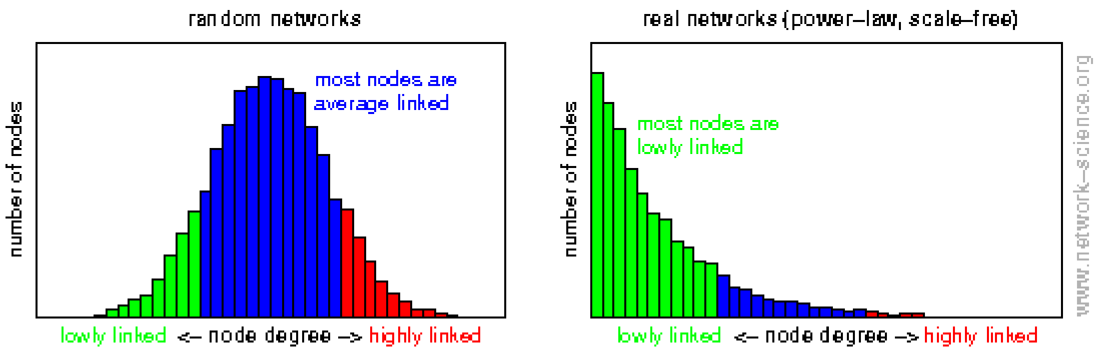


Figure 2. 2 Random and real networks (scale-free)

Network is a series of nodes or points which are tied or linked each other for communication in general. There are many different complex networks such as social networks, computer networks, telecommunication networks, biological networks, etc. Network science is multi-disciplinary academic area that studies complex network (Wasserman, 1994).

Complex network is a combination of large graphs which does not occur in simple networks, in the context of network theory. Each component of large graphs has its own internal structure with non-trivial topological features. We meet various networks in real life. For instances; the nodes are people and connections are friendship relations in social network and we can find another connection in a different way in same society such as siblings or marrieds. Complex network is a new area for scientific research in the study of real networks, computer networks and social networks (Solé and Valverde, 2004).

We are surrounded by systems that are complicated in the society. For example, it can be marriage relationships, family relations, coming together relations, visiting each other relations or partnership relations in a group. We can define a social network just by selecting one of these relationships. Cell phones, computers, satellites, neurons in our brain, interactions between thousands of genes and metabolites with-in our cells are good evidence of a world around us and within our body of unique real networks. Hence despite the amazing diversity in form, size, nature, age, and scope characterizing real networks, most networks observed in nature, society, and technology are driven by common organizing principle. However, it is difficult to find a mechanism to manage and to analyze these growing complex systems. Stephen Hawking says that "I think the next century will be the century of complexity." and it is inevitably "Networks at the heart of complex system." (Barabási, 2015f).

21st century is the century of social networks of information technologies which is at the heart of life starting from Google, Facebook, CISCO, and Twitter (Kwak et al., 2010). Furthermore, in Network Science, networks has become one the most important research areas today. There is a plot as seen in Figure 2.1, generated by Google Ngram, about the usage of words; network, quantum and evolution between 1980s and 2000s (Barabási, 2015f). Graph shows the increase of use of these words. The other words, quantum and evolution usage have stability after a while but network's increase goes on continually. The given importance to the network as scientific interest is increasing non-stop and people become having more social awareness about this issue (Ellison, 2007). That is to say, it should be also understood that the plot in the below indicates the exploding awareness of networks in the last decades of the 20th century, preparing a fertile ground for the emergence of network science. Hence, the significance of network directing us to study and analyze of it, network is the central core of this study.

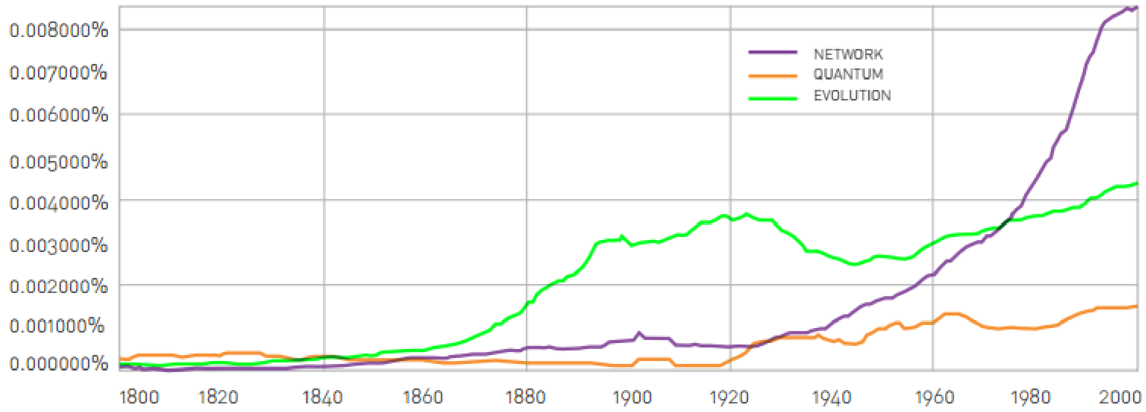


Figure 2. 3 The rise network (Barabási, 2015f)

2.2 Structure and Evolution of Online Social Networks

Firstly, studies about the social networks, their control mechanisms and their growth processes were the essential source for this study. Particularly, the study of structure and evolution of online social networks is a good example of the first detailed evaluation of the growth processes that control online social networks in large. The model is a very important to understand social networks from a structural point of view with its huge amount of social network data, Flickr and Yahoo. The study introduces a simple model of social network growth. Some of the properties of the network are defined and members of a social network are classified into three groups, named as the singletons, the giant component, and the middle region (Kumar, 2010). Our study is also consist of population whom we define with the characterization similar to this study, here we need to give their definitions since we used in our study in the same context.

- *Singletons* are the passive participant of the network who do not have any interaction with another participant. In graph theory view, they are zero-degree nodes. Our network data does not include singletons.
- *Giant component* is the largest group of user in the entire network who have made connections with each other thru paths. The most active users are among them.
- *Middle region* is the rest of the population apart from isolated ones and the largest group. They are not much actively participate in the network but interact a small number of users.

2.3 Evolving Networks

Furthermore, in order to get a detailed answer/understand which abilities, attributes, and differences of a node have a role in the increase of node degree. Here, a key question may be raised, how these differences effect the node's ability to acquire links. Therefore, random and scale free networks are the basic and principal phenomenon to start with. Since our study displays a scale free degree distribution, which we accept having not a fixed number of nodes and having any connection of random edges, we go with the related topics about the very common and a very important category of real networks, scale-free networks. Scale-free networks have common features, as follows (Hein et al., 2006).

- Self-organized, Dynamic, Evolving to larger number of size in time

- The growth principle of *the preferential attachment or linking:* While the network grows, its new vertex becomes preferentially attached to vertices with a high number of connections
- *Hubs* are formed as a result of this process. There is not an exact definition of hub in scientific literature. Hubs are connected nodes of large size which play a key role in the network properties (Barabási, 2014c).

Particularly, the concept of Scale-free networks have significantly developed after Barabási and his collaborators model. The Barabási-Albert model (BA model) is the basic growing network model that underlies two main characteristic, Growth and Preferential Attachment (Barabási, 2015a).

- *Growth:* A large variety of scale-free networks are growing, i.e. the number of nodes N in these networks is increasing with time. Example of growing scale-free networks are the World-Wide-Web, the Internet, Wikipedia, the citation networks, the movie actor networks, online social networks, etc. (Ellison, 2007).
- *Preferential Attachment*: In many of these networks the "popularity is attractive", meaning that the new links are not attached randomly but they follow the so called preferential attachment, i.e. node of high degree are more likely to acquire new nodes. For example, a new webpage is more likely connected to a well-known website (e.g. BBC, New York Times etc.) than to a rather unknown one. Similarly, highly cited papers are more likely to be cited again (Choromański et al., 2013).

The Barabási-Albert model centralizes the time dependence of the degree for nodes networks. To put it simply, each node increases its degree in time (Barabási, 2015b) . The resulting idea of the model is that if a node joins a network earlier, its degree will be larger. Hence it also means that late nodes can never become hubs. However, this is not enough to explain the reality. Sometimes a newcomer of a network may leave behind the earlier nodes. Therefore, this dilemma leads a question whether a node's growth depends on the node's age only. Barabási–Albert model states the degree of a node is proportional to a node's age, whereas The Bianconi- Barabási model asserts each individual node has its own dynamic exponent effecting the degree size. This model puts a clear definition, there are intrinsic / qualities that influence the rate at which a node make more links, calling it fitness of a node. As a consequence, we say that a node with a higher fitness will increase its degree in a short time. In real world, there are such situations such as Facebook, twitter in which we observe some users join late and have the most links within a short time. The figure given in the below makes a comparison between (fitness model) The Bianconi- Barabási and the Barabási–Albert model (Barabási, 2015c).

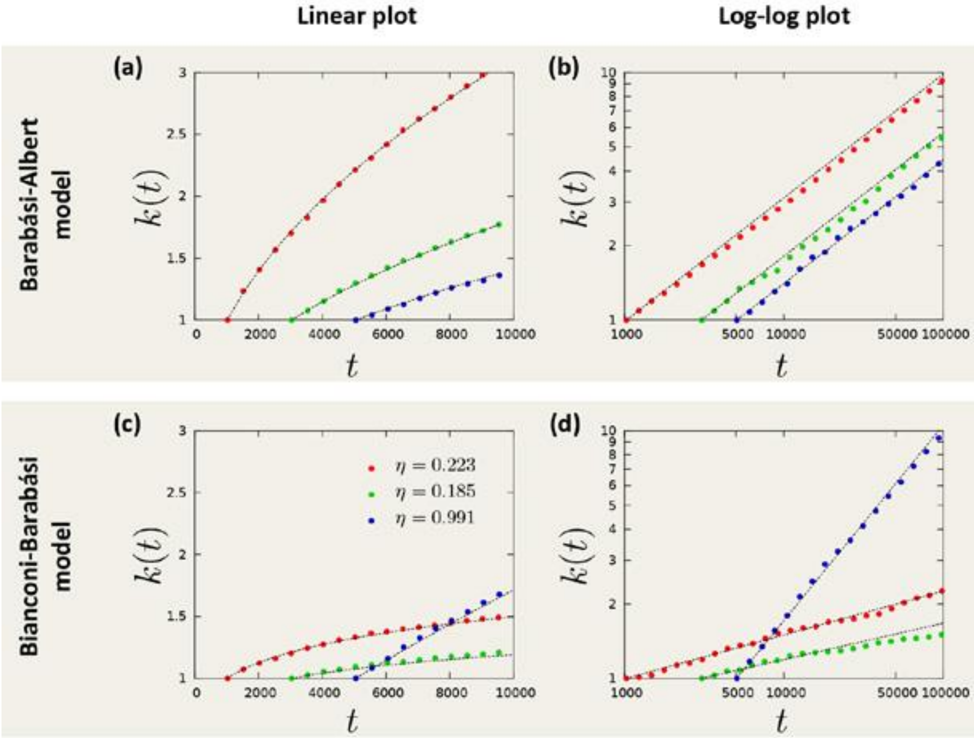


Figure 2. 4 The Bianconi- Barabási and the Barabási – Albert model

Researchers showed by further research that fitness of a node, an individual ability to acquire friends in a social network, is also heritable meaning that genetic roots.

2.4 Homophily /Assortative and Dissassortative Mixing

Networks, and especially social networks can also be characterized in terms of their *homophily or assortative mixing* and *dissassortative mixing* features (Clauset, 2013).

In many real networks, people prefer to have interaction with other people who have similar attributes, such as language, age, educational level, political beliefs, socioeconomic status, language and many others (Barabási, 2015d). For example, communities are formed with this tendency among individuals. Therefore, the society is a continuous system having assortative nature (Chang et al., 2007). Homophily is a social phenomenon captures the fact that individuals have a tendency to associate with other individuals of similar background and characteristics (Quayle et al., 2006).

In network view, assortative networks display common forms. General tendency of the hubs in assortative networks is to link to each other rather than small-degree nodes whereas the small-degree nodes tend to connect to other small-degree nodes (Bollen et al., 2011). In contrast to assortative networks, the hubs make linking mainly to small-degree nodes in dissassortative networks. Similarly, the opposite situation is also seen in some networks, which we call dissassortative mixing that presents a case of interactions between nodes with dissimilar attributes. For example, sexual contact networks are mostly dissassortative, interactions forming between men and women. Similarly, our network have dissassortativity among role and gender attributes, categorical variables such as vertex color, shape, race, nationality, gender, occupation, etc. In our study, we analyzed the hubs of online social health network and we observed that hubs tend to form edges with opposite attribute nodes; men with women mostly and visitors with physicians generally or vice versa.

The network assortativity can be a scalar attribute like vertex degree, age, weight, or income as told before. Moreover, in probability theory and statistics, covariance is also a kind of measure for the form of assortativity, a measure of how much two random variables X and Y change together (Barabási, 2014a). In a network with assortative mixing by degree the high-degree nodes will be preferentially connected to other high-degree nodes, and the low to low. Assortative mixing by degree produces a network in which the high-degree vertices tend to connect to each other, while the low-degree vertices also connect to each other. In these networks, degree correlates with centrality. On the contrary dissassortative mixing produces a network in which the high-degree vertices tend to connect to low-degree vertices, producing star-like structures (Università di Chieti-Pescara, 2015).

Chapter 3

Method

In this paper, the scope/results of the whole research is produced from analysis of the data of online social health network records in the year of 2012. Here, one year recorded data has a tie network characterization together with a total number of 2143 nodes and 5706 edges. The big part of the results is analyzed in the two open-source software applications, Gephi and MySQL. Gephi has been used for visualizing the social health network data content (Bastian et al., 2009). We examine the total interactions in the network. Gephi provides the dynamic visualizations, partitioning of each attribute in terms of gender or role and ranking as degree.

We try to describe the characteristics of 22 hubs constituting the top one percent (van Mierlo, 2014) of the nodes having the maximum degree (as we refer in the following part, The Barabási, "The Top One Percent") showed in tables and graphs (Barabási, 2014b). There is "one percent" phrase that refers to the income disparity. *"The "one percent" phrase has dominated the discourse during the 2012 US presidential election, reminding everyone that one percent of the population earns a disproportional 17.42% of the total US income."(Barabási, Ch 6, Pg. 10, Box 6.3)*

For the selected specific hubs, source and targets interactions are presented per week, describing the development of the edges formed in each week.

In the comparative analysis part, the whole analysis is summarized in a table, which presents the dissassortativity of Role and Gender, Degree, Hub Interaction, Time of Max Step (per week), Hub Development Path.

The data we have obtained from an online health platform, constitute a tie network which has reciprocal relations of 2012. The number of ties formed by these 22 hubs is 2798, constitute almost half of the total number of ties in the network. To better visualize edges between nodes we provide network models by YifanHu layout algorithm (see Figure 3.1) providing a visual representation that brings out the overall view of the network. The degree distribution of ties represented in graph (see Figure 3.2), which helps us to observe the minority of hub according to other nodes.

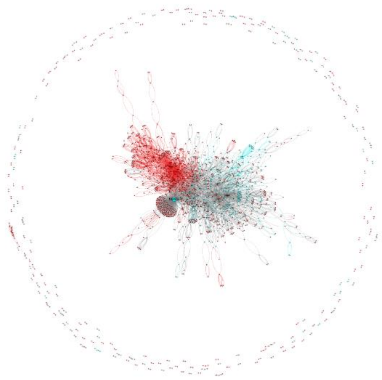


Figure 3. 1 Overall view of online health network

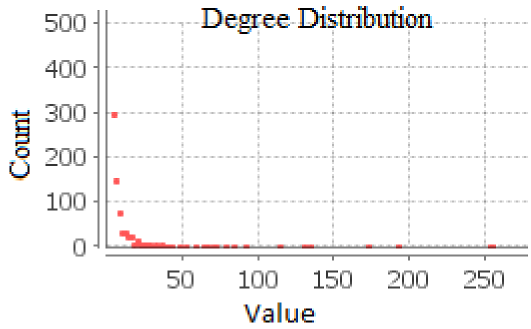


Figure 3. 2 Degree Distribution of online health network

Thanks to the data we have, we know the role and gender attributes of each hub and when they formed edge firstly in the network. We examine and analyse the weekly behaviours of hubs after joining the network at certain time. We used Gephi for visualisation in this research. Gephi provides dynamic analyse allows to observe the network growth monthly, we can see the growth of network from October to December, but we need to weekly analyse to better comprehend and detailed analysis, it is not available for now, there is no an particular feature available in Gephi. We investigated the weekly increase of hubs by using Excel. We examine and visualize by the graphs when the hubs form edge, on which time slot in a day, how much edge formed by hubs in which week of year, which attributed nodes are preferred previously for them or when they being passive or active in detail. So, we realized dynamic analysis with the static analysis of hubs in general.

In addition to these observations, we try to understand the common behaviours and grouping the hubs which have similar attributes. We observed dissassortativity for almost all hubs. Male visitors form edge with female physicians or female visitors or vice versa. Hubs not form edges only with hubs but also form edges with low-degree nodes mostly, and also sometimes hubs have no tie with any other hubs.

The ties of hubs increase after the middle of year mostly, hubs join the network at the beginning of year and become active towards end of year or join the network at the middle of year or towards end of year and raised their number of edge by forming edges in a week. However, some hubs become passive in time to time, and then become active again with reasons which we do not know. This structure exhibit staircases in graphs, some steps are long-timed and some steps are very small timed even shows continues (Albeverio et al., 2006). These behaviours are obstacles to have common discourse about hubs. However, we can have some ideas with general behaviours of hubs such as dissassortativity. Almost all hubs form edge with nodes which have opposite gender and role attributes in general; males with females and visitors with physicians or vice versa (Bollen et al., 2011). Additionally, as we stated before hubs become more active towards end of year.

Chapter 4

Results

4.1 Overall Analysis of Hubs

Id	Role	Gender	Date Start	Date End	Degree
1064632	Physician	M	27.07.2012 12:56	31.12.2012 23:59	338
1300836	Visitor	F	04.10.2012 20:38	31.12.2012 23:59	127
1083936	Visitor	M	10.01.2012 08:18	31.12.2012 23:59	126
312045	Visitor	F	19.08.2012 00:56	31.12.2012 23:59	96
745444	Visitor	M	09.01.2012 16:56	31.12.2012 23:59	86
1273971	Visitor	F	12.09.2012 00:56	31.12.2012 23:59	67
1086412	Physician	M	26.08.2012 16:37	31.12.2012 23:59	65
1066723	Physician	M	18.01.2012 14:33	31.12.2012 23:59	57
1310608	Visitor	M	16.10.2012 20:15	31.12.2012 23:59	46
1221746	Visitor	M	02.08.2012 08:11	31.12.2012 23:59	42
1100931	Visitor	M	08.02.2012 02:32	31.12.2012 23:59	39
1254004	Visitor	M	12.08.2012 16:30	31.12.2012 23:59	36
796973	Visitor	M	10.01.2012 21:01	31.12.2012 23:59	35
1135619	Visitor	F	05.09.2012 21:39	31.12.2012 23:59	33
655172	Visitor	F	13.07.2012 16:06	31.12.2012 23:59	32
967924	Physician	M	05.04.2012 01:10	31.12.2012 23:59	32
1162753	Visitor	M	17.07.2012 12:43	31.12.2012 23:59	29
488230	Visitor	M	11.09.2012 11:05	31.12.2012 23:59	26
875105	Visitor	F	18.01.2012 22:14	31.12.2012 23:59	24
186210	Physician	M	21.01.2012 16:35	31.12.2012 23:59	21
1090168	Visitor	M	09.01.2012 16:27	31.12.2012 23:59	21
1246687	Visitor	M	23.08.2012 09:16	31.12.2012 23:59	21

Table 4. 1 Basic characteristics of the hubs examined

This information health network has 2143 nodes and 5706 edges totally. We found that 22 maximum hubs that constitute approximately 50 per cent of the overall network interaction.

Notice that there is neither agreed definition nor exact values for hub, but it is worth noticing that 1% of total number of nodes is 21.43 so the chosen number of hubs is not so distinct from this number. Similarly, 50% of total network edges is 2853 and the chosen hubs have 2798 edges totally in the network.

Table 4.1 summarizes overall characteristics of hubs examined. Each hub is described by its id, role, gender, date (starting and ending timestamp) and degree. This is an undirected network (tie network which is derived from a directed network for those nodes which are reciprocated) so in-degree and out-degree values of nodes are equal. Also, we could see that starting dates of hubs are different since they join the network with different timestamps, but the end date of hubs is “31.12.2012 23:59” since we examine the data until the end of year 2012.

Source	Target	Role	Sex	Type	Id	Weight	R/A	Week	Date Start	Date End	Time Interval
1246687	28495	Visitor	F	Directed	2003	1.0	R	23	23.08.2012 09:16	31.12.2012 23:59	<[1.345702605E12, 1.35699114E12]>
1246687	1287210	Visitor	F	Directed	3515	1.0	R	40	01.10.2012 13:55	31.12.2012 23:59	<[1.349088915E12, 1.35699114E12]>
1246687	1135619	Visitor	F	Directed	4004	1.0	A	41	10.10.2012 10:58	31.12.2012 23:59	<[1.34985589E12, 1.35699114E12]>
1246687	488795	Visitor	F	Directed	4007	1.0	R	41	10.10.2012 11:01	31.12.2012 23:59	<[1.34985607E12, 1.35699114E12]>
1246687	1210275	Visitor	F	Directed	4019	1.0	R	41	10.10.2012 13:38	31.12.2012 23:59	<[1.349865498E12, 1.35699114E12]>
1246687	114221	Visitor	F	Directed	4021	1.0	R	41	10.10.2012 13:39	31.12.2012 23:59	<[1.34986556E12, 1.35699114E12]>
1246687	1306558	Visitor	F	Directed	4093	1.0	R	42	17.10.2012 09:51	31.12.2012 23:59	<[1.350456711E12, 1.35699114E12]>
1246687	537792	Visitor	F	Directed	4108	1.0	A	42	18.10.2012 15:03	31.12.2012 23:59	<[1.350561794E12, 1.35699114E12]>
1246687	1289236	Visitor	F	Directed	4111	1.0	R	42	19.10.2012 11:01	31.12.2012 23:59	<[1.350633717E12, 1.35699114E12]>
1246687	127503	Visitor	F	Directed	4273	1.0	R	44	30.10.2012 14:25	31.12.2012 23:59	<[1.351599955E12, 1.35699114E12]>
1246687	1319446	Visitor	F	Directed	4313	1.0	R	44	01.11.2012 09:26	31.12.2012 23:59	<[1.351754766E12, 1.35699114E12]>
1246687	606088	Visitor	F	Directed	4317	1.0	R	44	01.11.2012 10:56	31.12.2012 23:59	<[1.351760194E12, 1.35699114E12]>
1246687	85066	Visitor	F	Directed	4353	1.0	R	44	02.11.2012 08:44	31.12.2012 23:59	<[1.351838687E12, 1.35699114E12]>
1246687	595800	Visitor	F	Directed	4759	1.0	R	47	21.11.2012 14:33	31.12.2012 23:59	<[1.353501194E12, 1.35699114E12]>
1246687	1325312	Visitor	F	Directed	4761	1.0	R	47	21.11.2012 14:34	31.12.2012 23:59	<[1.353501254E12, 1.35699114E12]>
1246687	1135284	Visitor	F	Directed	4767	1.0	R	47	21.11.2012 15:01	31.12.2012 23:59	<[1.353502906E12, 1.35699114E12]>
1246687	674561	Visitor	F	Directed	4769	1.0	R	47	21.11.2012 15:03	31.12.2012 23:59	<[1.353502987E12, 1.35699114E12]>
1246687	416782	Visitor	F	Directed	4771	1.0	R	47	21.11.2012 15:06	31.12.2012 23:59	<[1.353503185E12, 1.35699114E12]>
1246687	1221746	Visitor	M	Directed	4785	1.0	R	47	22.11.2012 10:03	31.12.2012 23:59	<[1.35357139E12, 1.35699114E12]>
1246687	762225	Visitor	F	Directed	4956	1.0	A	48	30.11.2012 14:48	31.12.2012 23:59	<[1.354279681E12, 1.35699114E12]>
1246687	325168	Visitor	F	Directed	5250	1.0	A	50	12.12.2012 09:20	31.12.2012 23:59	<[1.355296839E12, 1.35699114E12]>

Table 4. 2 Detailed information on the edges of the Hub number 1246687

Table 4.2 shows a summary of the edges for the hub number 1246687. We provided such tables for each of hubs examined.

Thus, one can consider this table to demonstrate how an edge dataset is represented for hubs. In the edge table, we can see the target nodes which has relation with source hub. In the Table 4.2, the target column has id numbers of the nodes which are in relation with the source hub 1246687. Additionally, the role column indicates a role attribute of the target nodes which is physician or visitor and the gender column indicates a gender attribute of the target nodes which is female or male. R/A column presents the situation that source send request to the target node or accept request coming from target node; if the source hub sends request to a target node it means R, if source hub accepts request from target node it means A. The week column contains number of weeks which is the starting time for the network. Also; those, marked with yellow, are target nodes who are the hubs that has relation with the source hub.

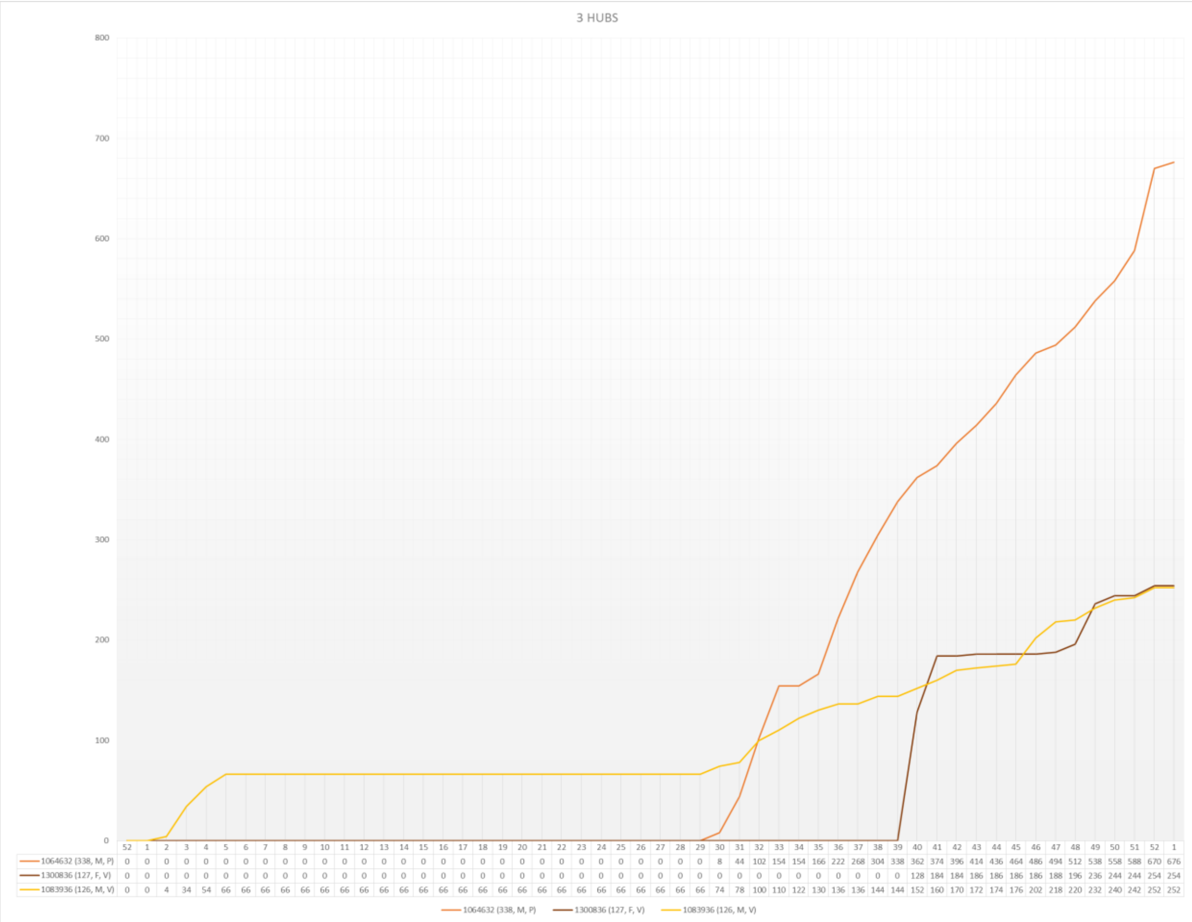


Figure 4. 1 The maximum three hubs as a general view

To make further examination of hubs we analyse them by comparing their development (that is, hub connections over time) and visualize it (see figures 4.1, 4.2, 4.3, 4.4 and 4.5).
We use labeling and coloring to better visualize development of the hubs and as you see each hub is described by its id and degree, gender and role attributes.

To better analyze general hub development we provide Figure 4.1 that shows how the largest three hubs have evolved over time. We consider a number of criteria to determine if and how certain characteristics hubs lead to specific hub development (might be called pattern).

We basically consider the following attributes for hub characterization. The gender attribute which has value of male or female, the next attribute is role which has the value of visitor or

physician. Thus, we have the following mixing attributes: female physicians, male physicians, female visitors and male visitors in the network.
To have better representation of each node type we choose for instance a male physician who has maximum degree 338 and id 1064632, a female visitor whose degree is 127 and id is 1300836, and a male visitor whose degree is 126 and id is 1083936. However, there is not a female physician in 22 maximum hubs.

The maximum two hubs start to have interactions in week 30 and 40, and they have the maximum edge numbers at the end of year; one of them is a male physician whose id is 1064632. The other one is a female visitor whose id is 1300836 but both of them become hub at the end of the year, despite they started to form edges in the middle of the year. In this manner, it is difficult to develop a common discourse for these three hubs.

The only common point that we observed step functions or "staircase" functions as a general behavior almost all of the hub graphs (Massey Jr, 1951). Staircase functions are those *functions whose graphs resemble sets of stairsteps are known as step functions* (Larson and Edwards, 2013).

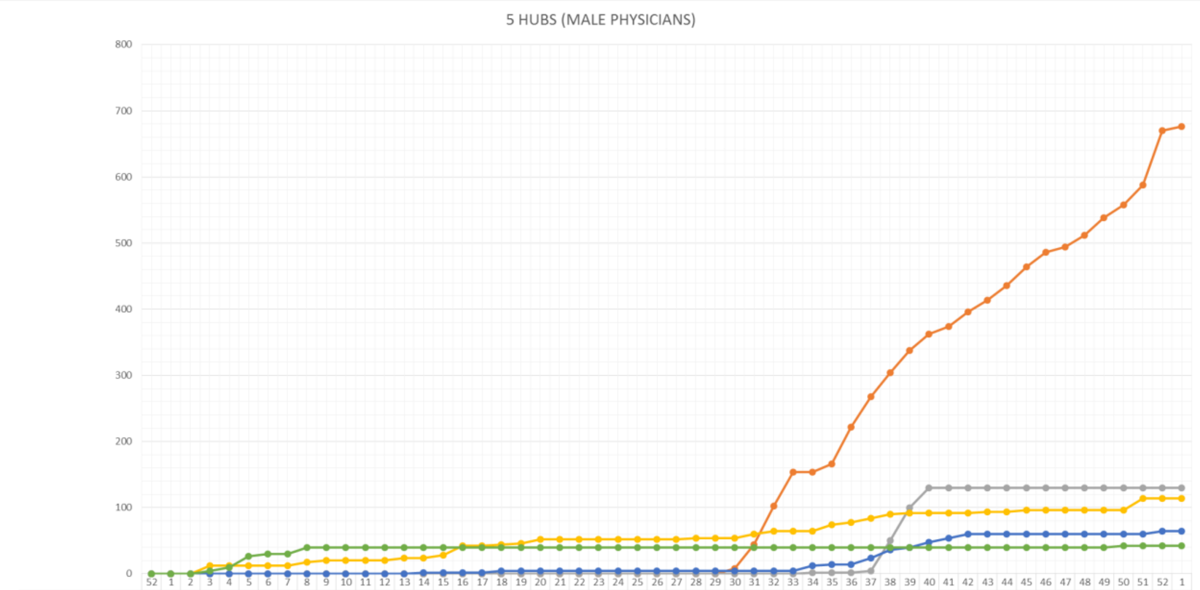
Let see how steps occurred for some hubs. Starting with the maximum hub, whose id is 1064632, it started with a step which is seen apparently on between the 29th and 34th weeks. The node, whose id is 1064632, has not got any edge on the 29th week but it has 8 edges on the 30th week, 44 edges on the 31st week, 102 edges on the 32nd week, 154 edges on the 33rd week, then it has a stability with 154 edges on the 34th week. Afterwards, it has increasing (see orange color) line until end of year.

The hub 1083936, has first step on 2nd week; it started to have interactions with 4 edges. Then it was continuing with a rising (yellow) line on the 3rd week and has 34 edges, with 54 edges on the 4th week, with 66 edges on the 5th week. Then first step of node 1083936 has stability until the 30th week. After the 30th week, rising continues with little steps; with 78 edges on the 31st week, with 100 edges on the 32nd week and so on. Steps ends with 252 edges on the 52nd week.

The hub 1300836, started to have interaction with 128 edges on the 40th week which is first week of her at the same time in network so it became apparent step between the 39th and the

41st week. She hasn't any edges on the 39th week but she has 128 edges on the 40th week and 184 edges on the 41st week. Then, we see a (lingering) slowly progress by brown line. Then, we see second step between the 48th and the 50th week; she has 196 edges on the 48th week, has 236 edges on the 49th week and 244 edges on the 50th week. Then, she has ongoing line by little increments.

There is no change in hub development between the 21st and the 27th weeks, this is due to the fact that the service on the platform was down, which is confirmed by the organization.



	52	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	1
1064632 (338, M, P)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	44	102	154	154	166	222	268	304	338	362	374	396	414	436	464	486	494	512	538	558	588	670	676
1086412 (65, M, P)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	4	50	100	130	130	130	130	130	130	130	130	130	130	130	130	130	130
1066723 (57, M, P)	0	0	0	12	12	12	12	12	18	20	20	20	20	24	24	28	42	42	44	46	52	52	52	52	52	52	52	52	54	54	54	60	64	64	64	74	78	84	90	92	92	92	92	94	94	96	96	96	96	96	96	114	114	114
967924 (32, M, P)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	2	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	12	14	14	24	36	40	48	54	60	60	60	60	60	60	60	60	60	60	64	64
186210 (21, M, P)	0	0	0	4	10	26	30	30	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	42	42	42	42

Figure 4. 2 Five male physician hubs

Figure 4.2 shows only physician hubs. All of them are male. That might bring another interesting question to what extent male hubs are dominant in creating connections for the whole network.

The hub 1064632, which is colored orange line, it has interesting line, he starts to have interactions by 8 edges on the 30th week and has a big step, then he continued to have edges with a rising line throughout the year and then become a maximum hub.

The hub, 1086412 is presented by a gray line, made steps between the 37th and the 40th weeks, the values are increases from 4 to 130. However, we see a stability after this, there is not any interaction until end of year.

The figure also shows that three hubs exhibit continues interactions. It is seen that three male physician hubs have parallel lines whose id are 1066723, 967924 and 186210. These three hubs have interactions regularly throughout the year. The hub 1066723, having interactions on a regular basis after the 3rd week and continued to form edges in remain weeks and made little steps which can be seen by the yellow line and become one of the maximum hub on the 51st week at the end of year. The hub 967924, which has a blue line, started to form edges on the 14th week, continued until 18th week. It is worth noticing that there is no interaction between on the 18th and the 33th week, it is observed that small increases happened after the 34th week. There is a break between on the 42nd and the 50th weeks again, but the hub finished the year with 64 edges at the end of the year. 186210 hub, which has green line, started to form edge in the 3rd week and one can see small steps until the 8th Week. It has 40 edges on the 8th week. However, there is no any interaction until the 50th Week. It has 42 edges on 50th week and then become one of hubs at the end of year.

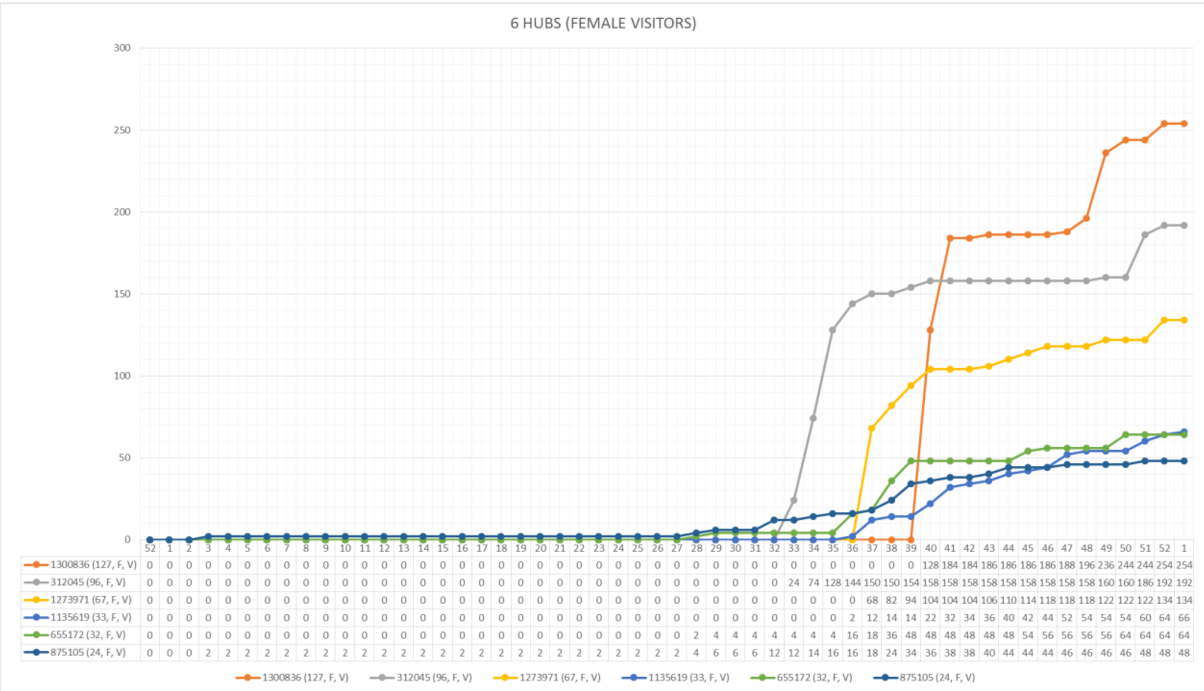


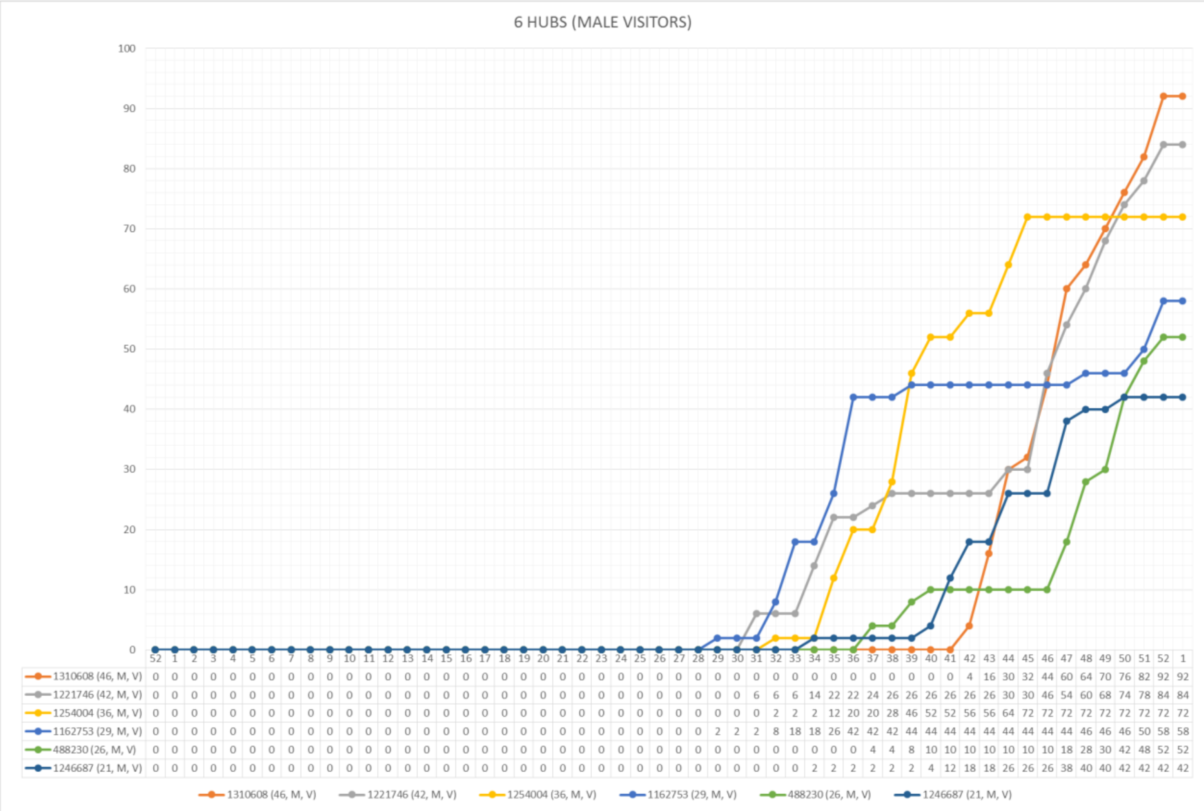
Figure 4. 3 Six female visitor hubs

As seen in Figure 4.3, the graph shows nodes which genders are female and roles are visitor. The general scene is that number of edge increases after the 28th week and they become hub at the end of year. Also, there are apparent steps functions on the graph. Hub 875105, 655172 and 1135619 have little steps, increments are small. For example, hub 1135619 has first step function started with 2 edges on the 36th week, then she has 12 edges on the 37th week, 14 edges on the 38th week and so on, as seen on light blue line. Hub 655172 has little steps, she started with 4 edges on the 35th week, then stairs goes to 16, 18, 36, 48 values but there is stability after the 39th week. However, there is a second stair goes to 54 and 56. Again there is a stability on 56 value but the last stair goes to 64 value at the end of year.

These six visitor female hubs displaying similar performances as progress, except hub 875105 whose degree is 24. She started to form edge on the 3rd week but she did not have any other interaction until the 28th week. However, after the 28th week, she continues to form edges regularly like other female visitor hubs. She has small steps again as in the example of the 31st week and the 32nd week that is seen on dark blue line.

Some hubs begins the network interaction forming too much edges at once. For example, hub 1300836 started to form edges with the biggest step on the week 40 Figure 4.3, and almost fifty percent of total edge number of it (128), is on this week. Then, she continues to form edges regularly as a year. Just like that, hub 1273971 started to form edges on the 37th week and more than fifty percent of total edge number of her, is on this week; her degree is 67 and she has 68 edges on the 37th week as seen on yellow line. Then, she continues to form edges throughout the year, too.

Hub 312045, started to form edge with a big step on the 33rd week as seen on gray line Figure 4.3, she continues regularly until the 40th week. Then she has break until the 49th week. However, there is second step starting the 50th week with 160 edges as seen on gray line; she starts and continues again having interactions regularly last weeks. It is not known starting and stopping results of hubs yet it is not known any contextual variables interested with nodes.



	52	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1310608 (46, M, V)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1221746 (42, M, V)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1254004 (36, M, V)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1162753 (29, M, V)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
488230 (26, M, V)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1246687 (21, M, V)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	1
1310608 (46, M, V)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	16	30	32	44	60	64	70	76	82	92	92
1221746 (42, M, V)	0	0	0	6	6	6	14	22	22	24	26	26	26	26	26	26	30	30	46	54	60	68	74	78	84	84
1254004 (36, M, V)	0	0	0	0	2	2	2	12	20	20	28	46	52	52	56	56	64	72	72	72	72	72	72	72	72	72
1162753 (29, M, V)	0	2	2	2	8	18	18	26	42	42	42	44	44	44	44	44	44	44	44	44	46	46	46	50	58	58
488230 (26, M, V)	0	0	0	0	0	0	0	0	0	4	4	8	10	10	10	10	10	10	10	18	28	30	42	48	52	52
1246687 (21, M, V)	0	0	0	0	0	0	2	2	2	2	2	2	4	12	18	18	26	26	26	38	40	40	42	42	42	42

Figure 4. 4 Six male visitor hubs

As seen in Figure 4.4, these are the six of whole male visitor hubs that consist of 50 percent all hubs. There are 22 hubs and 11 of them are male visitors. However, these six male visitors have a common discourse that despite all of them start to have interactions at the middle of the year, they become hub at the end of year. They have interactions on a regular basis until end of year which is presented increasing graph in general but they have breaks from time to time which we observed step functions on the graph Figure 4.4.

The six hubs have similar patterns except for orange hub whose id is 1310608. He has atipic behavior; he started to form edges on the 42^{nd} week with 4 edges, then he has 16 edges on the 43^{rd} week, 30 edges on the 44^{th} week and he continues regularly until the 52^{nd} week as seen on orange line Figure 4.4. The only hub which has no break is hub 1310608, he has dramatically increasing graph, and he has 92 edges only in ten weeks so he represents steep orange line as seen in Figure 4.4.

The hub 1221746 has somewhat similar behavior with hub 1310608. Again, he has increasing line; he joined the network on the 31st week so the first step on this week, second step is on the 35th week with 22 edges, then it increases to 24 and 26 and he has stability between 38 and 43 weeks, the other step is on the 44th week with 30 edges and continues regularly until the 52nd week as seen on gray line Figure 4.4.

The hub 1254004 started to have interaction with a small step with 2 edges on the 32nd week, then he has 12 edges on the 35th week, 20 edges on the 36th seen as step function on yellow line, the other steps seen on the 40th, the 42nd and the 45th weeks. He has 72 edges on the 45th week and there is not any other interaction after this week.

The Hub 1162753 which is colored light blue, starts to have edges on the 29th week until the 39th week. There is a break between the 39th and the 47th weeks. Then he continues to have edge until the 52nd week. The steps seen on the 29th week with 2 edges, on the 33rd week with 18 edges, on the 36th week with 42 edges, on the 39th week 44 edges, on the 48th week with 46 edges and on the 52nd week 58 edges.

The Hub 488230, which is colored green, joins the network on 37th week and continues regularly throughout the year, yet there is a break between 40 - 46 weeks. So, the steps seen on the 37th, 40th, 46th and 52nd weeks.

The Hub 1246687, which is colored dark blue, included the network on the 34th week yet there is a small break between the 34th and the 39th weeks, then he continues regularly until the 50th week. So the first step is on the 34th week, after a stable line until the 39th week, other steps seen on the 42nd, and 44th, 48th, 50th weeks.

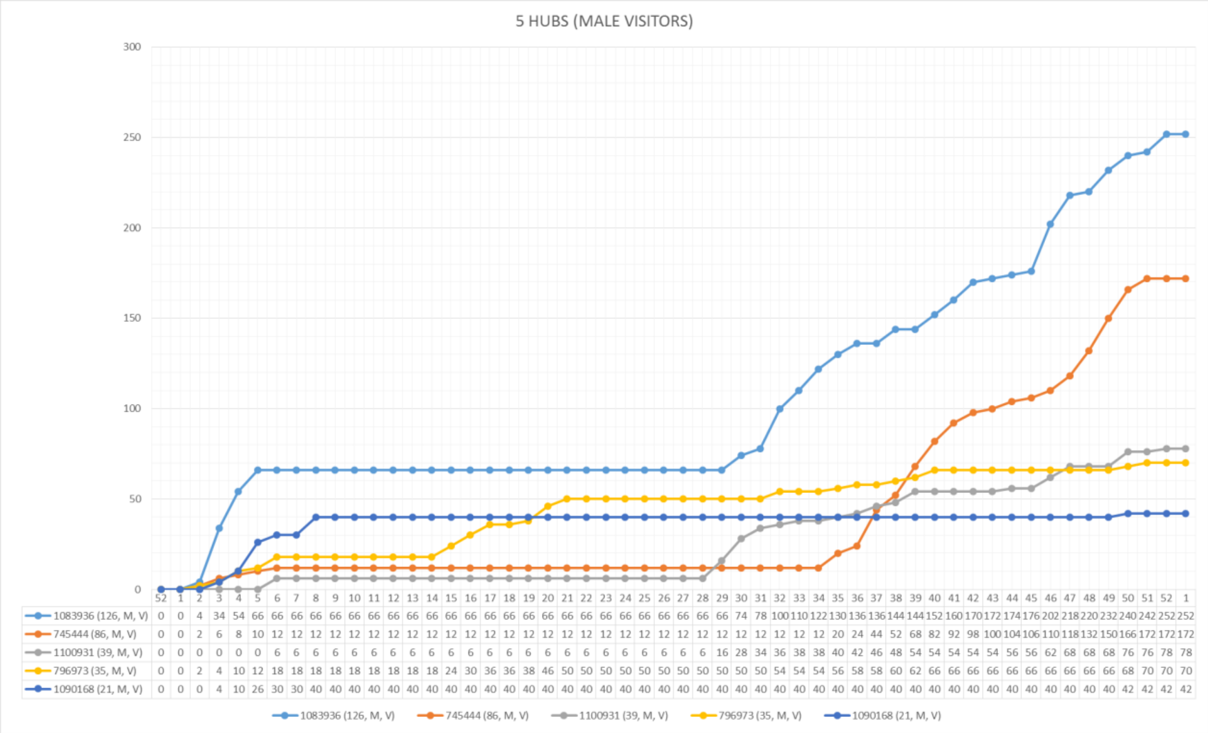


Figure 4. 5 Five male visitor hubs

As seen in Figure 4.5, there are persistent male visitor hubs that represent continues performance throughout the year. Although the graph continues, there are lots of ranges between interactions. They participate in the network, then they leave the network, afterwards they come back again.

For instance, the hub 1083936, started to form edges on the 5th week seen as the step which is colored light blue, but there is no further action until the 30th week. After the 30th week, there is a regular progress as increasing edge formation with small steps.

The hub 745444, which is colored orange, started to form edges on the 2nd week and continued until the 51st week, yet there is a break between the 6th and the 35th weeks so we observed apparent steps on the 6th week and the 51st weeks.

The hub 1100931, which is colored gray, starts to form edges on the 6th week until the 52nd week, yet there is a break between the 6th and the 29th weeks. So, we observed steps on the 6th week, then there are small steps on the 39th, 44th, 47th, 50th and the 52nd weeks.

The hub 796973, which is colored yellow, started to form edge on the 2nd week, yet there are breaks between the 6th and the 14th weeks, the 21st and the 31st weeks and the 40th and the 50th weeks, so we observed steps between these breaks.

The hub 1090168, which is colored dark blue, started to form edges on the 3rd week, yet there is a break between the 8th and the 50th weeks; he completed his interactions almost at the beginning of the year. The first step is seen on the 6th week with 30 edges, then the next step is on the 8th week by 40 edges and last step is seen on the 51st week with 42 edges.

4.2 Hub Specific Analysis

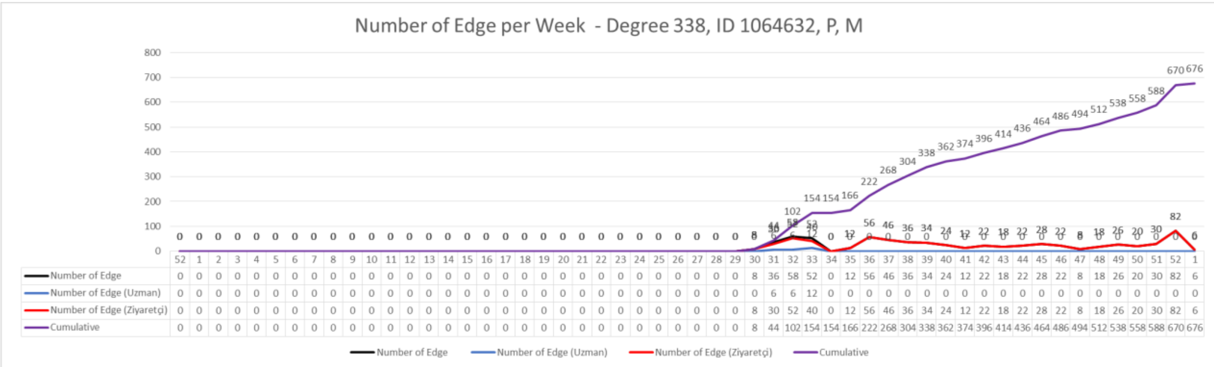


Figure 4. 6 Number of Edge per Week – Degree 338, ID 1064632, P, and M

	Female			***Male***		
	Accept	*Request*	*Sum*	*Accept*	*Request*	*Sum*
Physician	*0*	*10*	*10*	*0*	*2*	*2*
Visitor	*22*	*232*	*254*	*11*	*61*	*72*
Total				*338*		

Table 4. 3 Node attributes-specific edge statistics for the Hub number 1064632

As seen in Figure 4.6, this is the maximum hub of the network who is a male physician whose degree is 338, and id is 1064632. Most often, he sends requests to nodes whose role is "Visitor" and gender is "F" female as seen in the above table, and the mostly interactions with visitor females (Sum: 254).

There is a dissassortative relation with respect to the role and gender attributes. Namely, "Physician, M" has interaction mostly with "Visitor, F" (Requests: 232). He has edges with nodes whose role is "Physician" only on the 30th, the 31st and the 33rd weeks and most of them are female, and physician. Although he started to form edges on the 30th week, he continued regularly to form edges for the whole year, and he becomes maximum hub at the end of year. Also, this node has interactions generally in day times and sometimes at nights.

This node has interactions with hubs. He sends request to hubs which have degree 96 (312045, Z, K), 33 (1135619), 32 (655172, Z, K) and 29 (1162753, Z, E). Additionally, he accepted requests from hubs which have degree 127 (1300836, Z, K), 67 (1273971, Z, K) and 39 (1100931, Z, E). These interactions are generally on the 9th, 10th, 11st and 12th months.

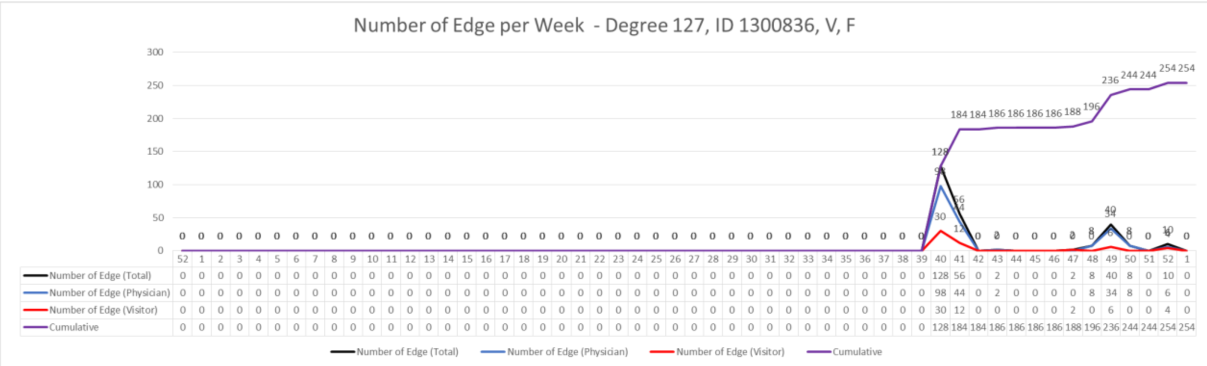


Figure 4. 7 Number of Edge per Week – Degree 127, ID 1300836, V, and F

	Female			***Male***		
	Accept	*Request*	*Sum*	*Accept*	*Request*	*Sum*
Physician	*1*	*11*	*12*	*26*	*89*	*115*
Visitor	*0*	*0*	*0*	*0*	*0*	*0*
Total				*127*		

Table 4. 4 Node attributes-specific edge statistics for the Hub number 1300836

As seen in the Figure 4.7, the second maximum hub has 127 degree, 1300836 ID. Its role is visitor and gender is female. She sends requests to nodes whose role is physician and gender is male in general. Again, as can be seen in the Table 4.4 there is dissassortative relation as role and gender; this visitor female has relation with 115 physician males.

Although she starts to form edges on 40th week, she becomes the maximum hub at the end of year. She has some breaks in general. However she has edges lots of number at once time when she participate in the network at the middle of the year.

This node has interactions especially between on the months 10 and 12 and in daytime. There is not any interactions at nights and there is not any interaction with visitors. All interactions of her, are with physicians.

She has interactions with two physician male hubs on the 10th month. One of them is hub that has 338 degree and 1064632 ID, the other one has 57 degree and 1066723 ID.

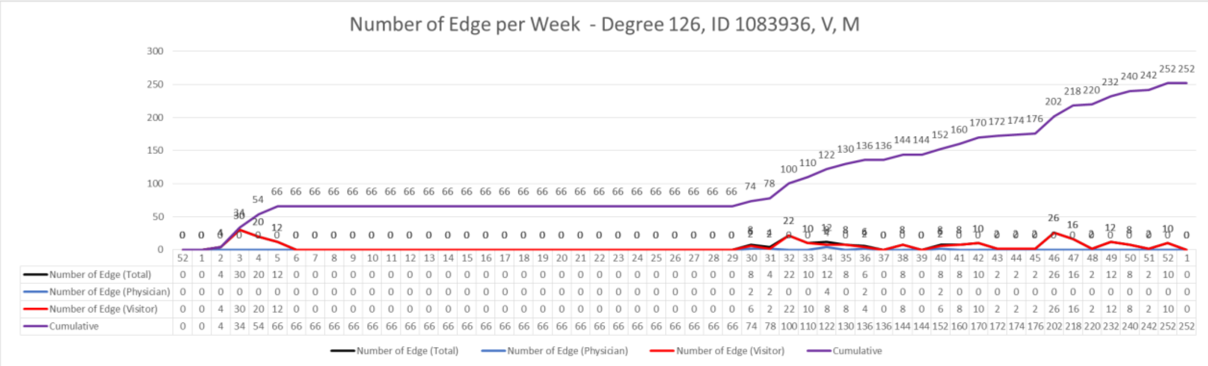


Figure 4. 8 Number of Edge per Week – Degree 126, ID 1083936, V, and M

	Female			***Male***		
	Accept	*Request*	*Sum*	*Accept*	*Request*	*Sum*
Physician	*0*	*0*	*0*	*0*	*0*	*0*
Visitor	*29*	*95*	*124*	*1*	*1*	*2*
Total				*126*		

Table 4. 5 Node attributes-specific edge statistics for the Hub number 1083936

As seen in the Figure 4.8, this hub is a male visitor that has 126 degree and 1083936 id. There is dissassortative relation as gender attribute. There is not any interaction with physicians. He sends requests to visitor females generally. As seen on the Table 4.5, he sends requests to 95 visitor females and one visitor male, accepts requests from 29 visitor females and one male.

He started to form edge on the 2nd week but he has break between the 5th and the 30th week. Then, he started to have interactions again and proceeds in an orderly manner until the 52nd week. Also, his interactions are in daytime in general.

In addition to these, he has interaction with one female visitor hub that has 24 degree and 875105 id. There is no any other hub interaction.

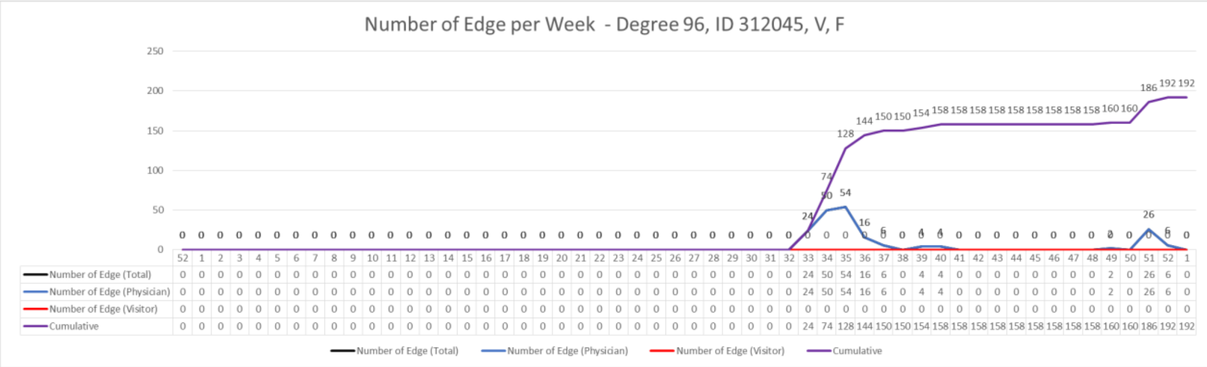


Figure 4. 9 Number of Edge per Week – Degree 96, ID 312045, V, and F

	Female			***Male***		
	Accept	*Request*	*Sum*	*Accept*	*Request*	*Sum*
Physician	*0*	*21*	*21*	*10*	*65*	*75*
Visitor	*0*	*0*	*0*	*0*	*0*	*0*
Total				*96*		

Table 4. 6 Node attributes-specific edge statistics for the Hub number 312045

As seen in the Figure 4.9, the hub that has 96 degree and 312045 id, is a female visitor. There is dissassortative relation again. All the interactions are occurred with male physicians.

As seen on the table, 21 requests are sent to physician females and 65 requests are sent to physician males, 10 requests are accepted from physician males.

The interactions start date is 19.08.2012 in the network and continues on the 8th, 9th, 10th and 12th months and generally at nights.

There are three hub interactions with physician males. Request accepted from hubs that has degree 338 and id 1064632 and hub that has degree 57 and id 1066723 on the 12th month. Request sent to hub whose degree is 65 and id is 1086412 on 8th month.

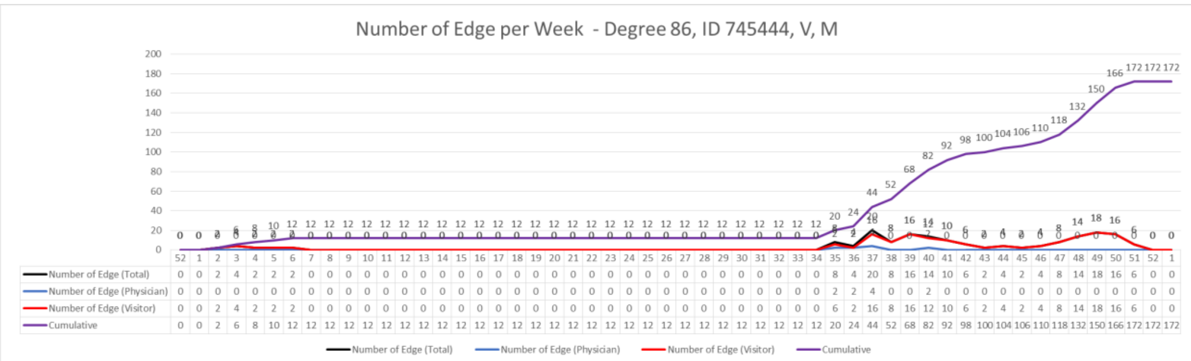


Figure 4. 10 Number of Edge per Week – Degree 86, ID 745444, V, and M

	Female			*Male*		
	Accept	*Request*	*Sum*	*Accept*	*Request*	*Sum*
Physician	*1*	*4*	*5*	*0*	*0*	*0*
Visitor	*20*	*61*	*81*	*0*	*0*	*0*
Total				*86*		

Table 4. 7 Node attributes-specific edge statistics for the Hub number 745444

As seen on the Figure 4.10, the hub that has 86 degree and 745444 id, is a male visitor. There is dissassortative relation again. Most of the interactions are occurred with female visitors.
As seen on the table, 61 requests are sent to female visitors and 4 requests are sent to physician females, 20 requests are accepted from female visitors and one requests are accepted from female physician.
The interactions start date is 09.01.2012 in the network and continues on the 2^{nd}, 8^{th}, 9^{th}, 10^{th}, 11^{th} and the 12^{th} months and generally in daytime. No interactions at nights.
There is only one hub interaction with a female visitor. Request sent to hub has 32 degree and 655172 degree on the 12^{th} month.

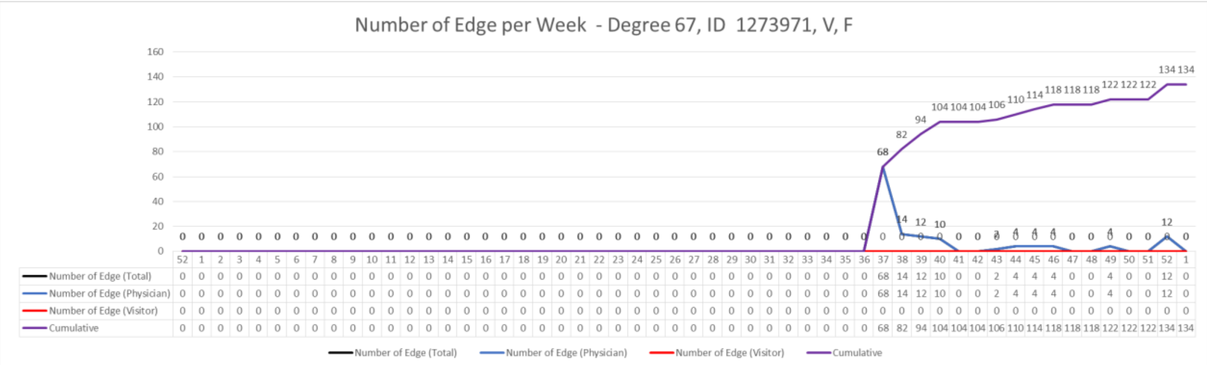


Figure 4. 11 Number of Edge per Week – Degree 67, ID 1273971, V, and F

	Female			*Male*		
	Accept	*Request*	*Sum*	*Accept*	*Request*	*Sum*
Physician	*1*	*8*	*9*	*6*	*52*	*58*
Visitor	*0*	*0*	*0*	*0*	*0*	*0*
Total				*67*		

Table 4. 8 Node attributes-specific edge statistics for the Hub number 1273971

As seen in the Figure 4.11, the hub that has 67 degree and 1273971 id, is a female visitor. The dissassortative relation is seen on both role and gender attributes in here. All the interactions are occurred with physicians and most them are males.

As seen on the Table 4.8, 52 requests are sent to male physicians and 8 requests are sent to female physicians, and 6 requests are accepted from male physicians and 1 request is accepted from female physician.

The interactions start date is 12.09.2012 in the network and continues on the 10th, 11th and 12th months, generally evenings and sometime afternoons.

There are three hub interactions are with male physicians. Requests are sent to hubs that; whose degree is 338 and id is 1064632, degree is 65 and id is 1086412, and degree is 57 and id is 1066723, on 9th month.

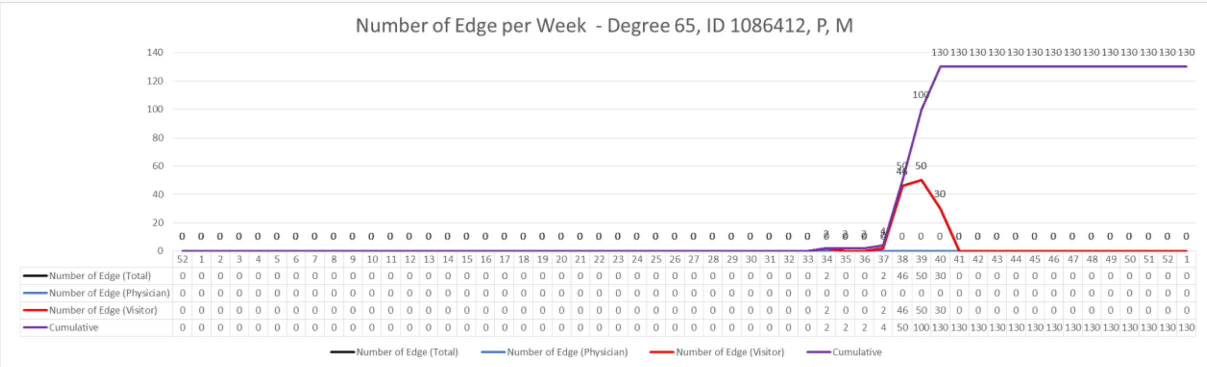


Figure 4. 12 Number of Edge per Week – Degree 65, ID 1086412, P, and M

	Female			**Male**		
	Accept	*Request*	*Sum*	*Accept*	*Request*	*Sum*
Physician	0	0	0	0	0	0
Visitor	4	56	60	0	5	5
Total				65		

Table 4. 9 Node attributes-specific edge statistics for the Hub number 1086412

As seen in the Figure 4.9, the hub that has 65 degree and 1086412 id, is a male physician. There are dissassortative relations again because of most of interactions are occurred with female visitors. Almost all interactions of this hub, are with visitors.

As seen on the Table 4.9, 56 requests are sent to female visitors and 5 requests are sent to male visitors, and 4 requests are accepted from female visitors.

The interactions start date is 26.08.2012 in the network and continues, then ends up on 10th month and generally in daytimes.

There are seven hub interactions with visitors. Requests are sent to female visitor hubs that; have 126 degree, 1300836 id; 33 degree, 1135619 id; 32 degree, 655172 id; 24 degree, 875105 id and sent to a male visitor hub who has 26 degree and 488230 id on 9th and 10th months. Requests are accepted from female visitor hubs that have 96 degree, 312045 id on 8th month and 67 degree, 1273971 id on 9th month.

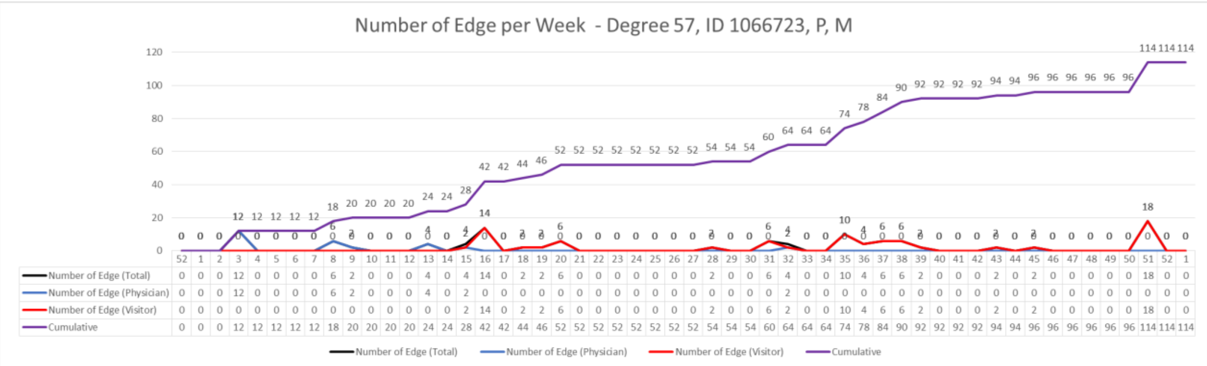


Figure 4. 13 Number of Edge per Week – Degree 57, ID 1066723, P, and M

	Female			***Male***		
	Accept	*Request*	*Sum*	*Accept*	*Request*	*Sum*
Physician	*10*	*3*	*13*	*0*	*1*	*1*
Visitor	*31*	*11*	*42*	*1*	*0*	*1*
Total				*57*		

Table 4. 10 Node attributes-specific edge statistics for the Hub number 1066723

As seen in the Figure 4.13, the hub that has 57 degree and 1066723 id, is a male physician. The dissassortative relation is seen on both role and gender attributes in here. Most of the interactions are occurred with female visitor hubs.

As seen on the Table 4.10, 11 requests are sent to female visitors, 3 requests sent to female physicians and one request is sent to a male physician. 31 requests are accepted from female visitors, 10 requests are accepted from female physicians and one request is accepted from a male visitor.

The interactions start date is 18.01.2012 in the network and continues on the 2nd, 3rd, 4th, 5th, 7th, 8th, 9th, 10th, 11th and the 12th months and generally daytimes and rarely at nights. There are lots of breaks between interactions.

There are three hub interactions are with female visitors. Request is sent to hub that; has 96 degree and 312045 id on the 12th month. Requests are accepted from hubs that has 127 degree, 1300836 id on 9th month and 67 degree, 1273971 id on the 10th month.

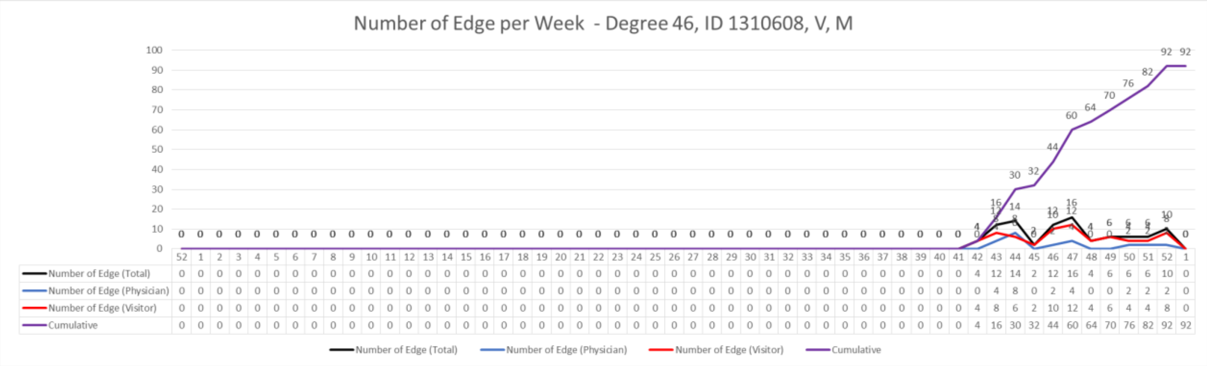


Figure 4. 14 Number of Edge per Week – Degree 46, ID 1310608, V, and M

	Female			***Male***		
	Accept	*Request*	*Sum*	*Accept*	*Request*	*Sum*
Physician	*3*	*9*	*12*	*0*	*0*	*0*
Visitor	*5*	*29*	*34*	*0*	*0*	*0*
Total				*46*		

Table 4. 11 Node attributes-specific edge statistics for the Hub number 1310608

As seen on the Figure 4.14, the hub that has 46 degree and 1310608 id, is a male visitor. The dissassortative relation is seen on gender attributes in here. There is not any edge with male nodes. All of the interactions are occurred with female nodes.

As seen on the Table 4.11, 29 requests are sent to female visitors and 9 requests sent to female physicians. 5 requests are accepted from female visitors and 3 requests are accepted from female physicians.

The interactions start date is 16.10.2012 in the network and continues on the 11th and the 12th months and generally daytimes, there is not any interactions at nights.

There is one hub request to a female visitor that has 33 degree and 1135619 id on the 10th month.

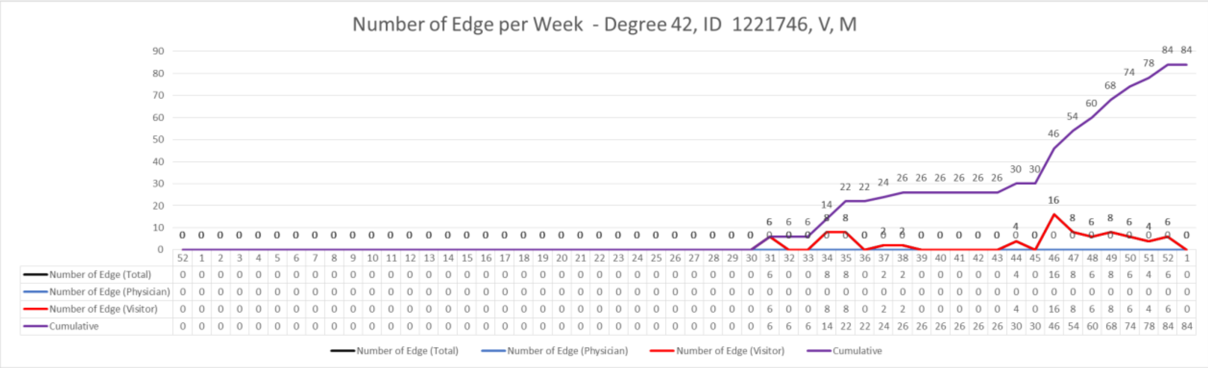


Figure 4. 15 Number of Edge per Week – Degree 42, ID 1221746, V, and M

	Female			**Male**		
	Accept	*Request*	*Sum*	*Accept*	*Request*	*Sum*
Physician	0	0	0	0	0	0
Visitor	8	33	41	1	0	1
Total				42		

Table 4. 12 Node attributes-specific edge statistics for the Hub number 1221746

As seen on the Figure 4.15, the hub that has 42 degree and 1221746 id, is a male visitor. The dissassortative relation is seen on gender attributes in here. Most of the interactions are occurred with female visitors.

As seen on the Table 4.12, 33 requests are sent to female visitors, 8 requests are accepted from female visitors and 1 request is accepted from male visitor.

The interactions start date is 02.08.2012 in the network and continues on the 9th, 10th, 11th and the 12th months and generally in daytimes.

There are two hub interactions. The request is accepted from female visitor hub that has 33 degree and 1135619 id on the 10th month. Request is sent to male visitor hub that has 21 degree and 1246687 id on the 11th month.

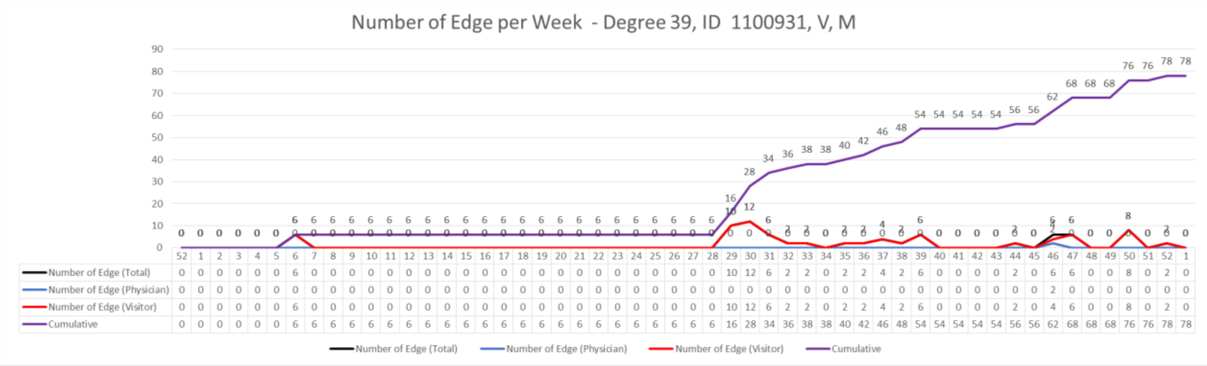


Figure 4. 16 Number of Edge per Week – Degree 39, ID 1100931, V, and M

	Female			***Male***		
	Accept	*Request*	*Sum*	*Accept*	*Request*	*Sum*
Physician	*0*	*0*	*0*	*0*	*1*	*1*
Visitor	*8*	*30*	*38*	*0*	*0*	*0*
Total				*39*		

Table 4. 13 Node attributes-specific edge statistics for the Hub number 1100931

As seen on the Figure 4.16, the hub that has 39 degree and 1100931 id, is a male visitor. The dissassortative relation is seen on gender attributes in here. Most of the interactions are occurred with female visitors.

As seen on the Table 4.13, 30 requests are sent to female visitors, 8 requests are accepted from female visitors and only 1 request is sent to a male physician.

The start date of interactions is 08.02.2012 in the network and continues on the 9th, 10th, 11th and the 12th months and evenings or nights.

There are two hub interactions. One request is sent to female visitor hub that has 32 degree and 655172 id on the 7th month. The other request is sent to a male physician hub whose degree is 338 and id is 1064632 on the 11th month.

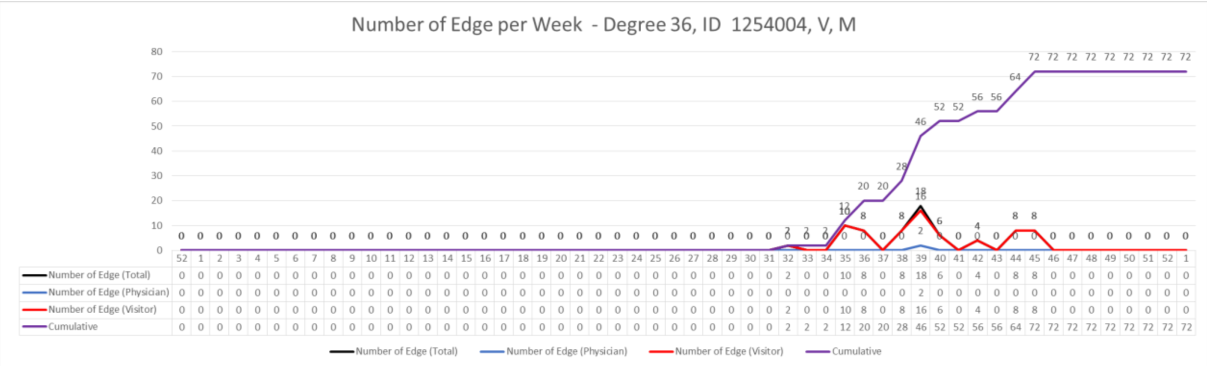


Figure 4. 17 Number of Edge per Week – Degree 36, ID 1254004, V, M

	Female			***Male***		
	Accept	*Request*	*Sum*	*Accept*	*Request*	*Sum*
Physician	*0*	*0*	*0*	*0*	*1*	*1*
Visitor	*5*	*29*	*34*	*0*	*1*	*1*
Total				*36*		

Table 4. 14 Node attributes-specific edge statistics for the Hub number 1254004

As seen on the Figure 4.17, the hub that has 36 degree and 1254004 id, is a male visitor. The dissassortative relation is seen on gender attributes in here. Most of the interactions are occurred with female visitors.

As seen on the Table 4.14, 29 requests are sent to female visitors, 5 requests are accepted from female visitors. 1 request is sent to a male visitor and 1 request is sent to a male physician.

The interactions start date is 12.08.2012 in the network and continues on the 9th, 10th and the 12th months and generally in the evening or at nights.

There is not any interaction with hubs.

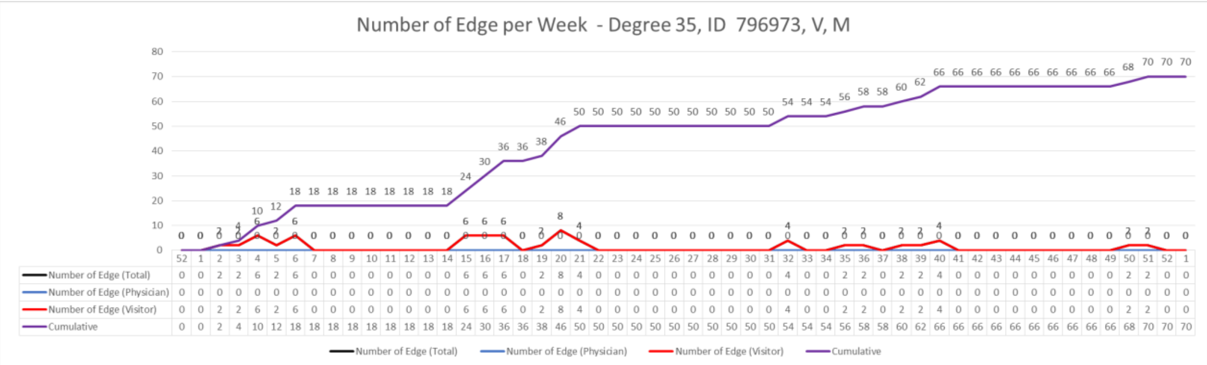


Figure 4. 18 Number of Edge per Week – Degree 35, ID 796973, V, M

	Female			***Male***		
	Accept	*Request*	*Sum*	*Accept*	*Request*	*Sum*
Physician	*0*	*0*	*0*	*0*	*0*	*0*
Visitor	*20*	*15*	*35*	*0*	*0*	*0*
Total				*35*		

Table 4. 15 Node attributes-specific edge statistics for the Hub number 796973

As seen on the Figure 4.18, the hub that has 35 degree and 796973 id, is a male visitor. The dissassortative relation is seen on gender attributes in here. All of the interactions are occurred with female visitors.

As seen on the Table 4.15, 15 requests are sent to female visitors, 20 requests are accepted from female visitors. There is not any interaction with physicians.

The interactions start date is 10.01.2012 in the network and continues on the 2nd, 4th, 5th, 8th, 9th, 10th, and the 12th months and generally in the evenings. It can be seen apparent steps on the 6th, 21st and the 40th weeks by the graph Fig. 4.18.

There is not any interactions with hubs.

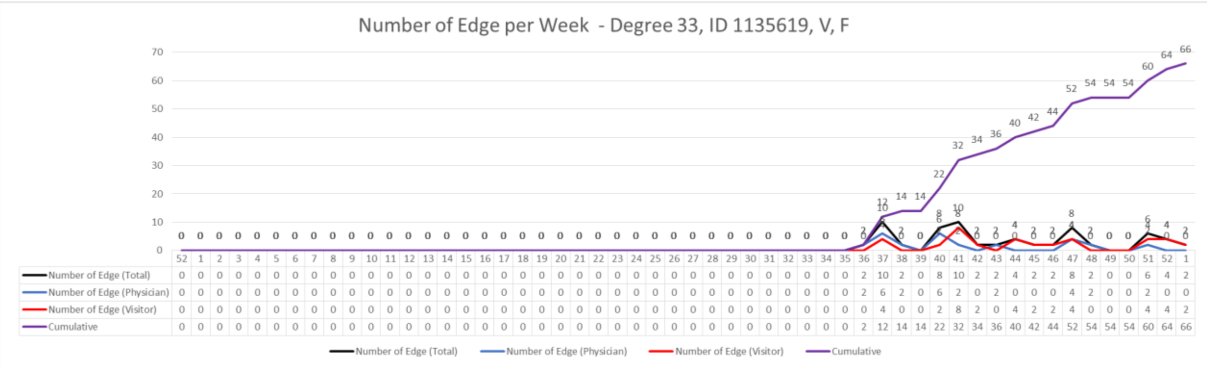


Figure 4. 19 Number of Edge per Week – Degree 33, ID 1135619, V, and F

	Female			***Male***		
	Accept	*Request*	*Sum*	*Accept*	*Request*	*Sum*
Physician	*0*	*0*	*0*	*6*	*8*	*14*
Visitor	*1*	*0*	*1*	*9*	*9*	*18*
Total				*33*		

Table 4. 16 Node attributes-specific edge statistics for the Hub number 1135619

As seen on the Figure 4.19, the hub that has 33 degree and 1135619 id, is a female visitor. The dissassortative relation is seen on gender attributes in here. Most of the interactions are occurred with male visitors.

As seen on the Table 4.16, 9 requests are sent to male visitors, 9 requests are accepted from male visitors and 8 requests are sent to male physicians, 6 requests are accepted from male physicians. There is one interaction with a female visitor.

The interactions start date is 05.09.2012 in the network and continues on the 10th, 11th and the 12th months and generally in daytime. It can be seen apparent steps on the 38th and the 48th weeks by the graph Fig. 4.19.

There are eight hub interactions. The request is accepted from male visitor hub that has 26 degree and 488230 id on the 11th month, male physician hub that has 32 degree and 967924 id on the 10th month, male physician hub that has 338 degree and 1064632 id on the 9th month, male physician hub that has 65 degree and 1086412 id on the 9th month, male visitor hub that has 46 degree and 1310608 id on the 10th month and male visitor hub that has 29 degree and 1162753 id on the 12th month. The request is sent to male visitor whose id 1221746 and 1246687 on the 10th months.

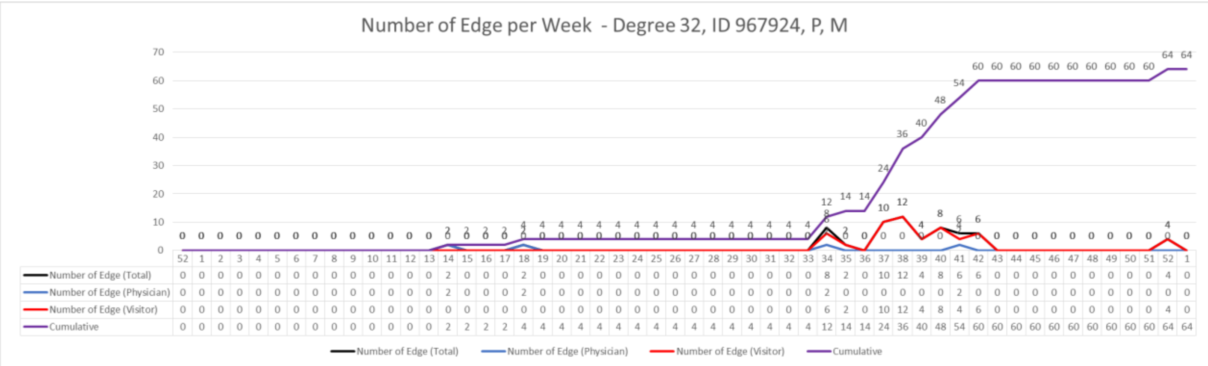


Figure 4. 20 Number of Edge per Week – Degree 32, ID 967924, P, and M

	Female			***Male***		
	Accept	*Request*	*Sum*	*Accept*	*Request*	*Sum*
Physician	*1*	*1*	*2*	*1*	*1*	*2*
Visitor	*2*	*26*	*28*	*0*	*0*	*0*
Total				*32*		

Table 4. 17 Node attributes-specific edge statistics for the Hub number 967924

As seen on the Figure 4.20, the hub that has 32 degree and 967924 id, is a male physician. The dissassortative relation is seen on gender and role attributes in here. Most of the interactions are occurred with female visitors.

As seen on the Table 4.17, 26 requests are sent to female visitors, 2 requests are accepted from female visitors and 1 request is sent to a female physician, 1 request is accepted from a male physician. 1 request is sent to a male physician, 1 request is accepted from a male physician.

The interactions start date is 05.04.2012 in the network and continues on the 5th, 8th, 9th, 10th and the 12th months and generally in daytime. It can be seen apparent steps on the 18th, 35th and the 42nd weeks by the graph Fig. 4.20.

There are three hub interactions. The requests are sent to female visitors whose id is 875105 on the 9th month and whose id is 1300836 and 1135619 on the 10th month.

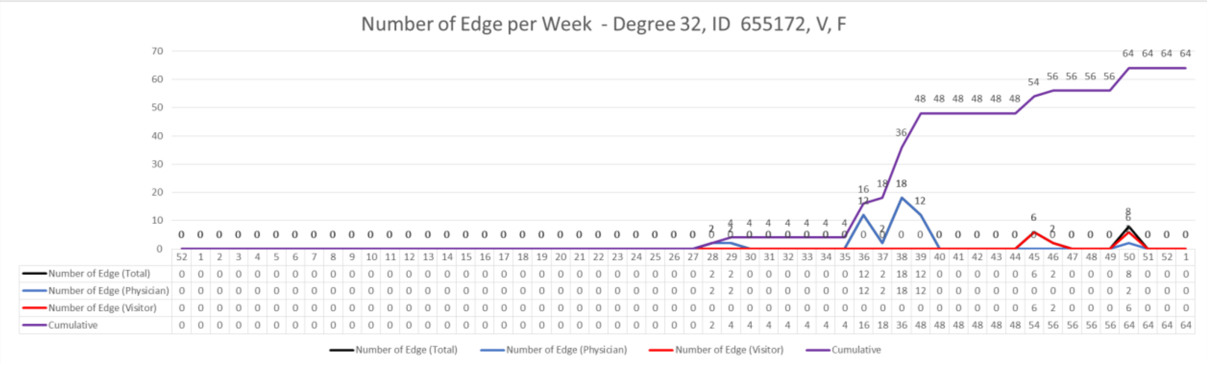


Figure 4. 21 Number of Edge per Week – Degree 32, ID 655172, V, and F

	Female			***Male***		
	Accept	*Request*	*Sum*	*Accept*	*Request*	*Sum*
Physician	*0*	*0*	*0*	*8*	*22*	*30*
Visitor	*0*	*0*	*0*	*2*	*0*	*2*
Total				*32*		

Table 4. 18 Node attributes-specific edge statistics for the Hub number 655172

As seen on the Figure 4.21, the hub that has 32 degree and 655172 id, is a female visitor. The dissassortative relation is seen on gender and role attributes in here. Most of the interactions are occurred with male physicians.

As seen on the Table 4.18, 22 requests are sent to male physicians, 8 requests are accepted from male physicians and 2 requests is accepted from male visitors.

The interactions start date is 13.07.2012 in the network and continues on the 7th, 9th, 11th and the 12th months and generally in daytime. It can be seen apparent steps on the 29th, 39th, 46th and the 50th weeks by the graph Fig. 4.21.

There are four hub interactions. The requests are accepted from male visitors whose id is 1100931 on the 7th month and whose id is 74544 on the 12th month, and from male physicians whose id is 1086412 and whose id is 1064632 on the 9th month.

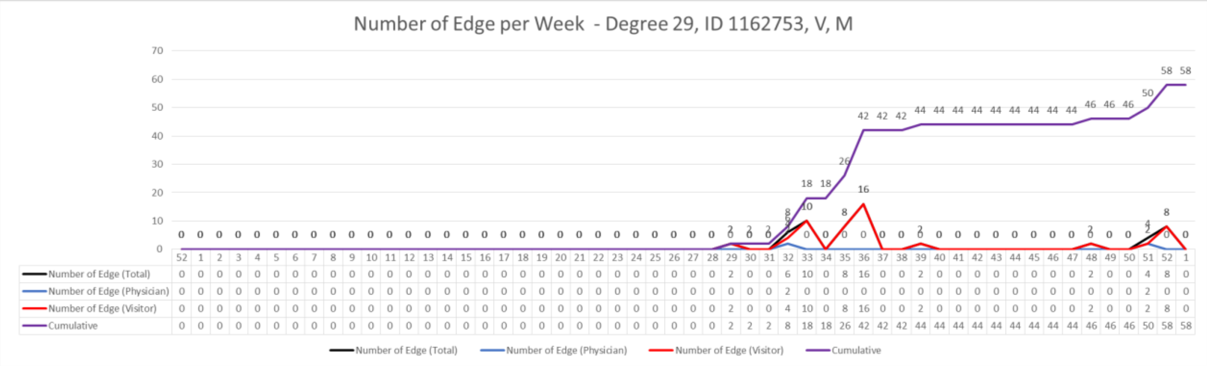


Figure 4. 22 Number of Edge per Week – Degree 29, ID 1162753, V, and M

	Female			***Male***		
	Accept	*Request*	*Sum*	*Accept*	*Request*	*Sum*
Physician	*0*	*1*	*1*	*1*	*0*	*1*
Visitor	*0*	*26*	*26*	*1*	*0*	*1*
Total				*29*		

Table 4. 19 Node attributes-specific edge statistics for the Hub number 1162753

As seen on the Figure 4.22, the hub that has 29 degree and 1162753 id, is a male visitor. The dissassortative relation is seen on gender attribute in here. Most of the interactions are occurred with female visitors.

As seen on the Table 4.19, 26 requests are sent to female visitors, 1 request is sent to female physician. 1 request is accepted from male visitor and 1 request is accepted from male physician.

The interactions start date is 17.07.2012 in the network and continues on the 8th, 9th, 11th and the 12th months and generally in daytime and sometimes at nights. It can be seen steps on the 33rd, 36th, 39th, 48th and the 52nd weeks by the graph Fig. 4.22.

There are two hub interactions. The requests are accepted from male physician whose id is 1064632 and the request is sent to a female visitor whose id is 1135619 on the 12th month.

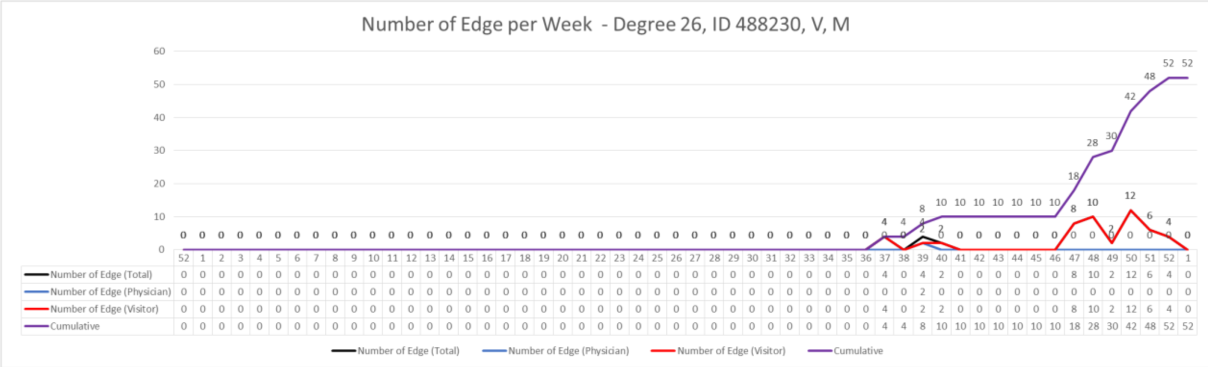


Figure 4. 23 Number of Edge per Week – Degree 26, ID 488230, V, and M

	Female			**Male**		
	Accept	*Request*	*Sum*	*Accept*	*Request*	*Sum*
Physician	0	0	0	1	0	1
Visitor	2	21	23	1	1	2
Total				26		

Table 4. 20 Node attributes-specific edge statistics for the Hub number 488230

As seen on the Figure 4.23, the hub that has 26 degree and 488230 id, is a male visitor. The dissassortative relation is seen on gender attribute in here. Most of the interactions are occurred with female visitors.

As seen on the Table 4.20, 21 requests are sent to female visitors, 1 request is sent to male visitor. 2 requests are accepted from female visitors, 1 request is accepted from male physician and male visitor.

The interactions start date is 11.09.2012 in the network and continues on the 9th, 10th, 11th and the 12th months and generally in daytime. It can be seen steps on the 40th and the 52nd weeks by the graph Fig. 4.23

There are two hub interactions. The request is accepted from male physician whose id is 1086412 and the request is sent to a female visitor whose id is 1135619 on the 11th month.

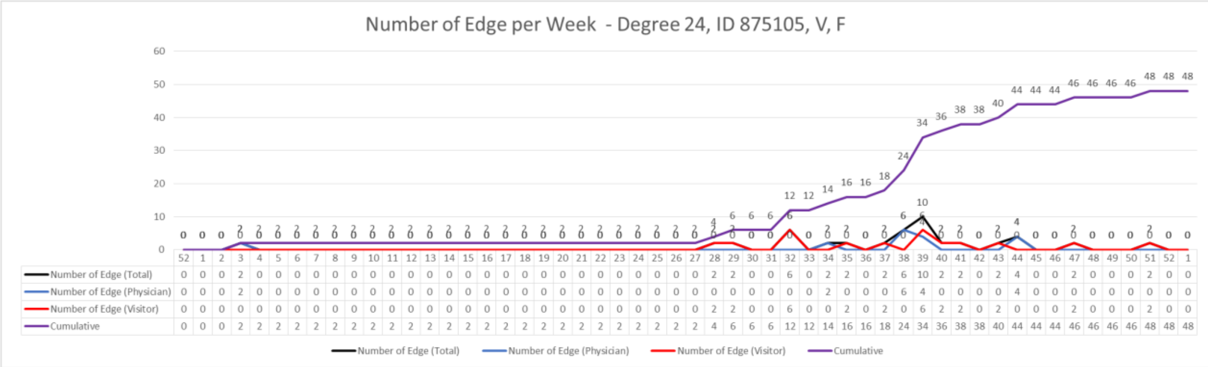


Figure 4. 24 Number of Edge per Week – Degree 24, ID 875105, V, F

	Female			**Male**		
	Accept	*Request*	*Sum*	*Accept*	*Request*	*Sum*
Physician	0	0	0	6	3	9
Visitor	3	0	3	11	1	12
Total				24		

Table 4. 21 Node attributes-specific edge statistics for the Hub number 875105

As seen on the Figure 4.24, the hub that has 24 degree and 875105 id, is a female visitor. The dissassortative relation is seen on gender attribute in here. Most of the interactions are occurred with male visitors.

As seen on the Table 4.21, 3 requests are sent to male physicians, 1 request is sent to a male visitor. 6 requests are accepted from male physicians, 11 request is accepted from male visitors and one request is accepted from a female visitor.

The interactions start date is 18.01.2012 in the network and continues on the 7th, 8th, 9th, 10th, 11th and the 12th months and generally in the evenings. It can be seen steps on the 3rd, 29th, 32nd, 44th, 47th and the 51st weeks by the graph Fig. 4.24.

There are four hub interactions. The request is accepted from male physicians whose id is 1086412 and whose id is 967924 and the request is sent to a male visitor whose id is 1254004 on the 9th month. The request is accepted from a male visitor hub whose id is 1083936 on the 8th month.

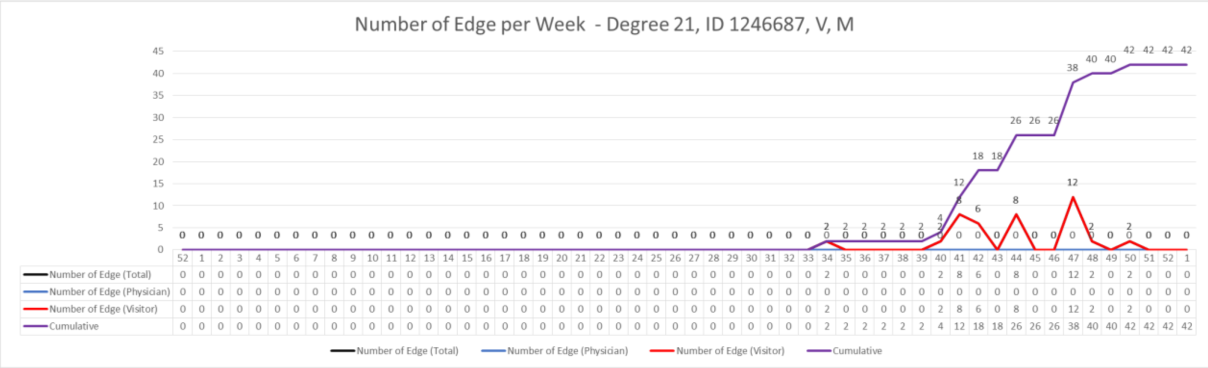


Figure 4. 25 Number of Edge per Week – Degree 24 ID 1246687, V, and M

	Female			**Male**		
	Accept	*Request*	*Sum*	*Accept*	*Request*	*Sum*
Physician	0	0	0	0	0	0
Visitor	14	7	21	0	0	0
Total				21		

Table 4. 22 Node attributes-specific edge statistics for the Hub number 1246687

The hub that has 24 degree and 1246687 id, is a male visitor.

As seen on the Table 4.22, 3 requests are sent to female physicians, 1 request is sent to a male physician. 7 requests are accepted from female physicians, 10 requests are accepted from male physicians.

The interactions start date is 23.08.2012 in the network and continues on the 8th, 10th, 11th and the 12th months and generally in daytime. It can be seen steps on the 34th, 42nd, 44th, 48th and the 50th weeks by the graph Fig. 4.25.

There are two hub interactions. The request is accepted from a female visitor whose id is 1135619 on the 10th month and the request is sent to a male visitor whose id is 1221746 on the 11th month.

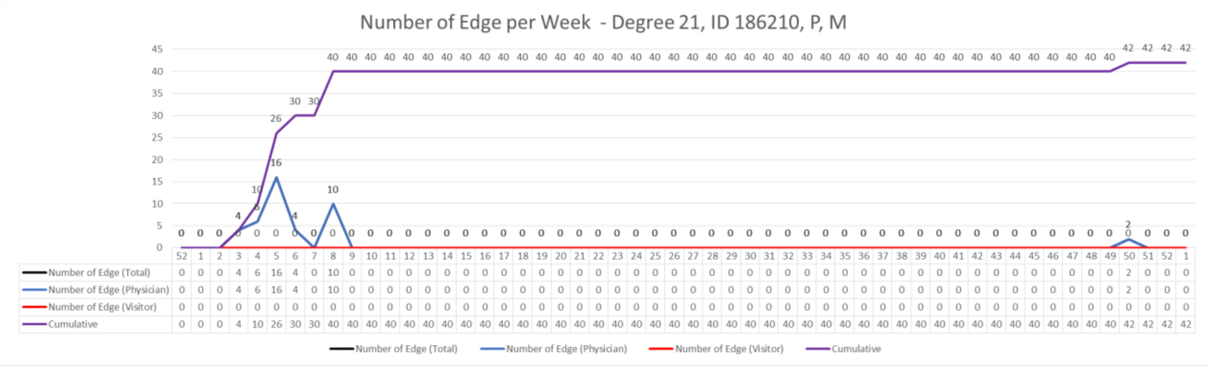


Figure 4. 26 Number of Edge per Week – Degree 21, ID 186210, P, and M

	Female			**Male**		
	Accept	*Request*	*Sum*	*Accept*	*Request*	*Sum*
Physician	0	0	0	0	0	0
Visitor	14	7	21	0	0	0
Total				21		

Table 4. 23 Node attributes-specific edge statistics for the Hub number 186210

As seen on the Figure 4.26, the hub that has 21 degree and 186210 id, is a male physician. The dissassortative relation is seen on gender and role attributes in here. Most of the interactions are occurred with female visitors.

As seen on the Table 4.23, 16 requests are sent to female visitors, 1 request is sent to a male visitor. 4 requests are accepted from female visitors.

The interactions start date is 21.01.2012 in the network and continues on the 2nd and the 12th months and generally in the evenings. It can be seen steps on the 6th, 8th and the 50th weeks by the graph Fig. 4.26.

There is not any hub interactions.

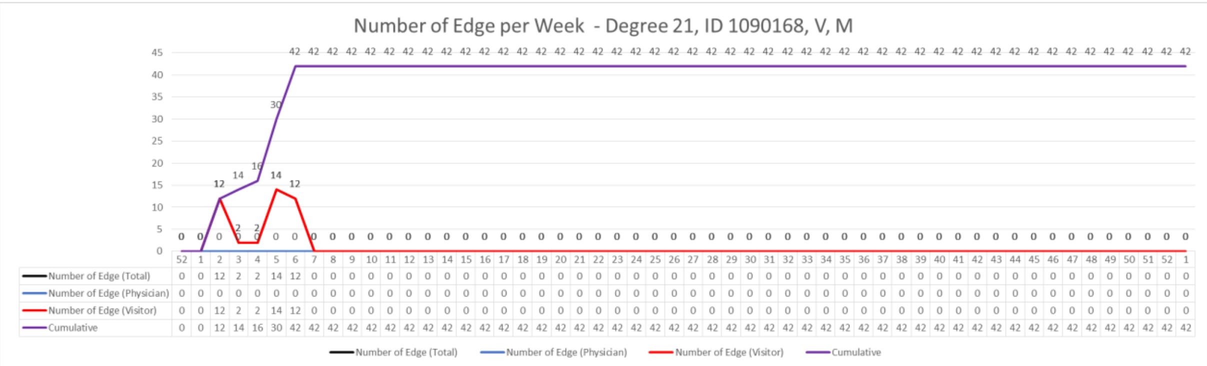


Figure 4. 27 Number of Edge per Week – Degree 21, ID 1090168, V, M

	Female			**Male**		
	Accept	*Request*	*Sum*	*Accept*	*Request*	*Sum*
Physician	0	0	0	0	0	0
Visitor	14	7	21	0	0	0
Total				21		

Table 4. 24 Node attributes-specific edge statistics for the Hub number 1090168

As seen on the Figure 4.27, the hub that has 21 degree and 1090168 id, is a male visitor. The dissassortative relation is seen on gender attribute in here. All of the interactions are occurred with female visitors.

As seen on the Table 4.24, 7 requests are sent to female visitors, 14 request is accepted from female visitors.

The interactions start date is 09.01.2012 in the network and continues on the 2nd month and generally in daytimes. It can be seen apparent step starting on the 6th week by the graph Fig. 4.27.

There is not any hub interactions.

Total Interactions in the Network:

	Female			**Male**		
	Accept	*Request*	*Sum*	*Accept*	*Request*	*Sum*
Physician	24	71	95	75	246	321
Visitor	178	687	865	38	80	118
Total				1399		

Table 4. 25 Total Interactions of Hubs examined

As we noted in our study with detailed hub analysis, total interactions state in Table 4.25. Hubs forming edges with visitors generally and most of them are female. Subsequently, the following relations with physician males. As we mentioned before, there are 2798 reciprocal ties, which is almost the fifty percent of total edge number forming by hubs in this network.

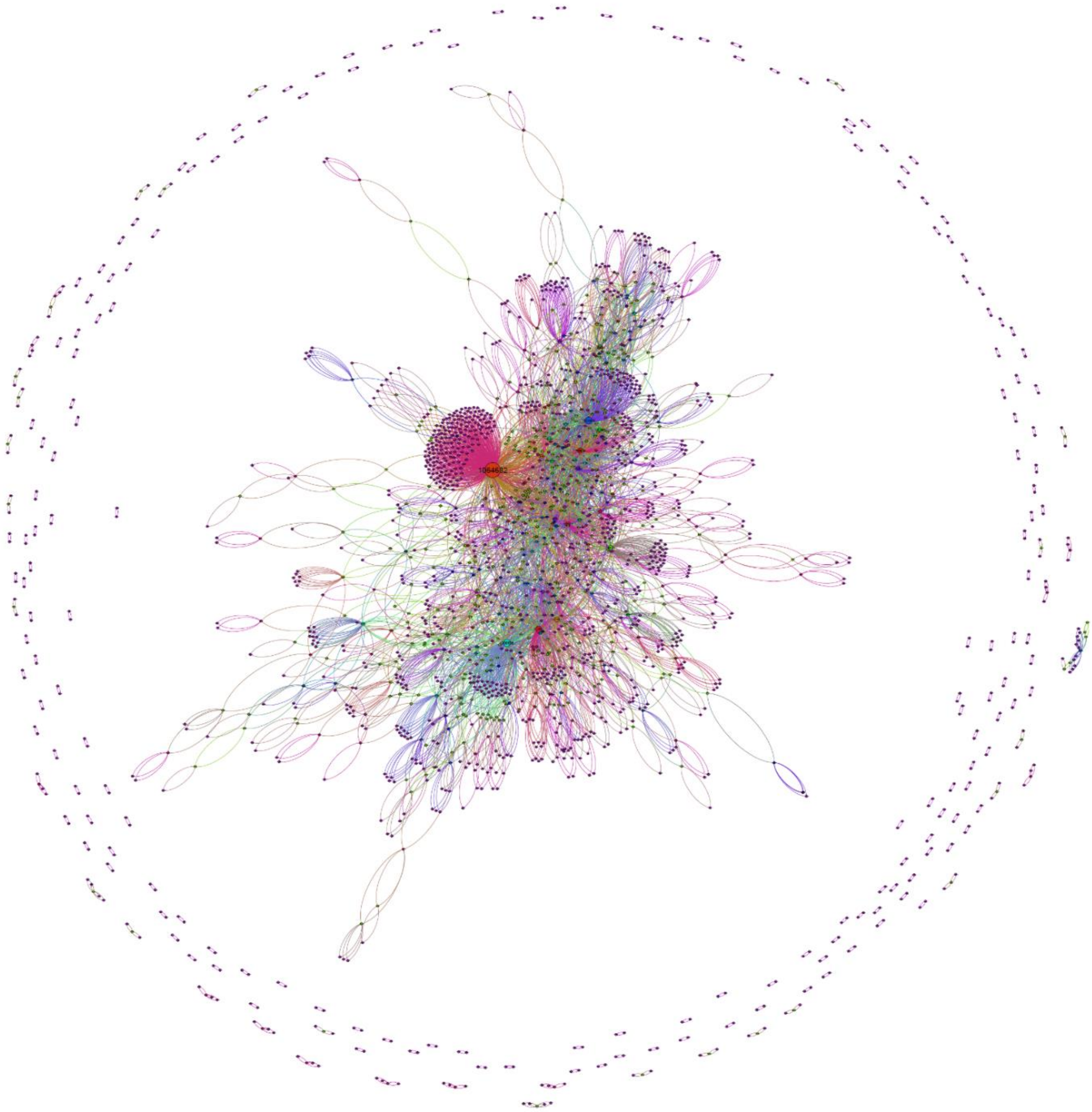


Figure 4. 28 Online Health Network Interactions based on degree representation

As seen on the table, there are various nodes which have different degrees. We visualize them according to the degree of size. The maximum hub has the largest circle which is red and labeled by id 1064632. Hubs, who has bigger circles in network can be seen in Figure 4.28, has lots of edges with little degree nodes. Also, we see small interactions formed by small degree nodes around of the giant component.

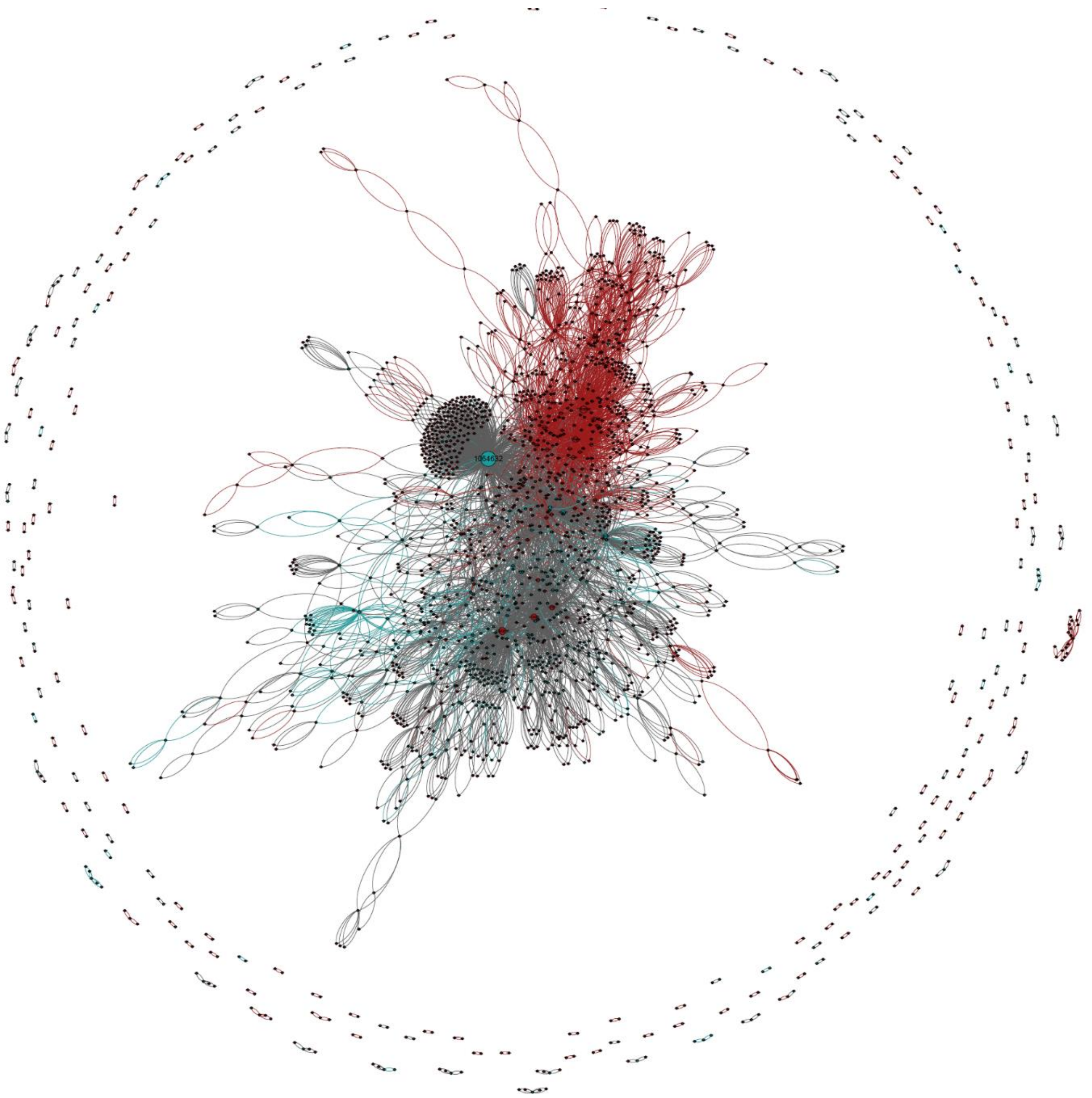


Figure 4. 29 Online Health Network Interactions based on the role attribute

As seen on the table, there are lots of visitors of this online social network. Visitors are 74.48 percentage of this network and colored red. Physicians are 25.52 percentage of the network and colored blue. Red edges are forming between visitors, blue edges forming between physicians and gray edges forming between visitor and physician.

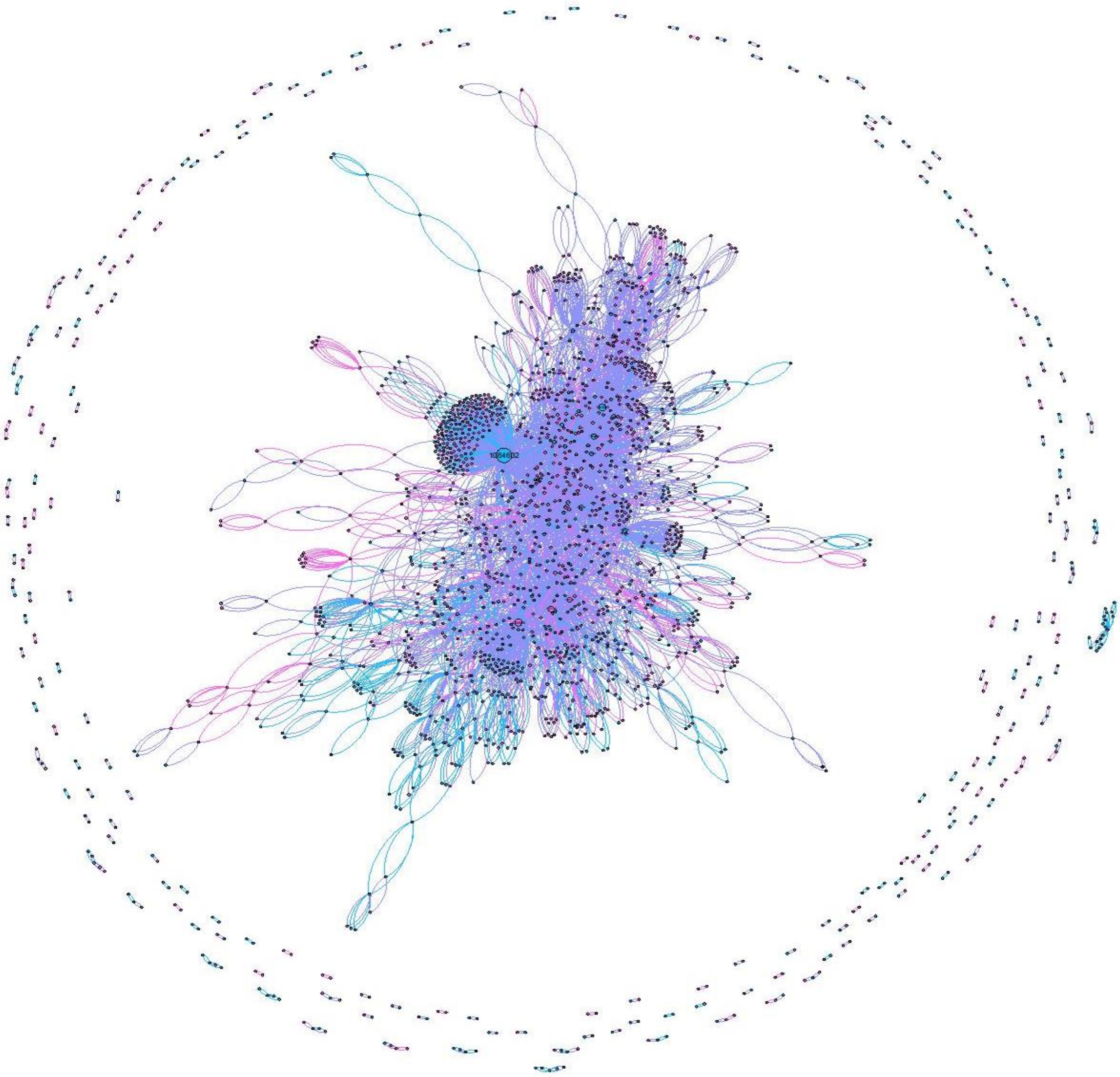


Figure 4. 30 Online Health Network Interactions based on the gender attribute

59.64 percent of the network is male and colored by light blue and 40.36 percent of the network is female which is colored by pink. Edges are light purple between male and female. Blue edges are between males and pink edges are between females. It is obviously seen that light purple edge color dominant in network because of dissassortative relations in the online health platform that we try to reveal in our study with the analysis.

4.3 Comparative Analysis

Hub		Disassortativity		Hub Interaction	Time of Max Step (per week)	Hub Development Path
ID	**Degree**	**Role**	**Sex**			
1064632	338	✓	✓	5	4	Starts in the middle of the year + monoton increase dramatically (has atipic steep line)
1300836	127	✓	✓	2	2	Starts towards end of the year + big jump + sleep + monoton increase
1083936	126	X	✓	1	4	Starts beginnings of the year with a step + sleep + monoton increase
312045	96	✓	✓	3	5	Starts towards end of the year + jump + sleep sometimes + monoton increase
745444	86	X	✓	1	5	Starts beginnings of the year with a step + sleep + monoton increase
1273971	67	✓	✓	3	4	Starts towards end of the year + jump + sleep sometimes + monoton increase
1086412	65	✓	✓	7	4	Starts in the middle of the year + step + straight
1066723	57	✓	✓	3	6	Starts at the beginnings of the year + sleeps sometimes + slightly increase
1310608	46	X	✓	1	3	Starts towards end of the year + jump + monoton increase dramatically (has atipic steep line)
1221746	42	X	✓	2	3	Starts towards end of the year + jump + sleep + monoton increase
1100931	39	X	✓	2	6	Starts beginnings of the year with a small step + sleep + slightly increase
1254004	36	X	✓	0	4	Starts towards end of the year + jump + monoton increase + sleep
796973	35	X	✓	0	5	Starts beginnings of the year with a small step + sleep sometimes + slightly increase
1135619	33	X	✓	8	3	Starts and become active towards end of the year + slightly increase
655172	32	✓	✓	4	5	Starts in the middle of the year + sleeps sometimes + become active towards the end of the year + slightly increase
967924	32	✓	✓	3	7	Starts at the beginnings of the year + sleeps sometimes + slightly increase
1162753	29	X	✓	2	3	Starts towards end of the year + jump + monoton increase + sleep + monoton increase
488230	26	X	✓	2	4	Starts towards end of the year with a step + sleep + jump + monoton increase
875105	24	X	✓	4	8	Starts at the beginnings of the year + sleeps + become active towards the end of the year + slightly increase
186210	21	✓	✓	0	4	Starts at the beginnings of the year + sleeps sometimes + slightly increase
1090168	21	X	✓	0	4	Starts beginnings of the year with a small step + sleep + slightly increase
1246687	21	X	X	2	4	Starts towards end of the year with a small step + sleep + jumps + monoton increase

Table 4. 26 Comparative Analysis of Hubs

To better understand hub development we analyze comparatively and colored them by overall analysis groups. Blue represents male physicians, oranges are visitor females, grays are visitor male and yellows are visitor males which have apparent steps. We analyze dissassortativity, hub interaction, step times and hub developments of chosen hubs. We observed that there are dissassortative interactions almost all of them hubs; nine of them have both heterotrophic relation as role and gender attributes and the others have dissassortative gender interaction as seen in the Table 4.26. There are hub interactions but we cannot say the relations go on hubs, conversely edges forming with nodes who are not a hub, in general. Time of steps represent that hubs reach their maximum numbers in between 2 or 8 week. Hub development path shows that same colors present similar behaviors, our overall analysis groups reveals the network realities for hubs. They sometimes begin starting of year or at the end of year, or sometimes sleep or jump, some of them slightly increase or dramatically increase but all of them are hubs at the end of year.

Chapter 5

Discussion

5.1 Implications for Network Science

Given various hub development behaviors it is not viable to make a classification for the hubs examined. We do not have the knowledge of any contextual variables about the chosen hubs but we can group them in terms of their similar behaviors as seen in the Table 4.26 for this study. The time we got the data, it was not a necessity to give special information in the membership area, but it is a requirement to subscribe the Doktorsitesi.com by giving information such as education, occupation, birth-date, mobile phone, country, city for now (Aydin and Perdahci, 2013).

The most prominent feature, which we observed in this online social health network, appears to be dissassortativity; hubs form edges with different role or gender nodes. Actually, almost all hubs form edges in the opposite gender. Also, they prefer to form edges with different role nodes in general. For instance, blues are male physicians, in Comparative Analysis Table 4.26, all of them have both heterophonic relation as role and gender, and it means that male physicians prefer to form edges with female visitors.

Additionally, the hubs have interactions with other hubs but not mostly, they form edges with the other nodes in general. When we look at the hub interaction column, we see that the values change between 0 and 8. For instances, the maximum hub has interactions with 338 nodes and 5 of them are hubs. This hub value (5) is not a big value for the total node numbers (338) but it is sufficient value for total hub numbers (22). However, we observed that it is not a determinant feature for being hub because we see that two distinct examples; there are two hubs who have a similar degree value; the hub 796973 whose degree is 35, has not got any hub interaction but the hub 1135629 whose degree is 33 has the maximum hub interaction value 8.

The time of the max step for top one percent 22 hubs changes between the 2nd and 8th weeks. Normal network nodes turn into hubs in those periods generally and mostly become active towards the end of the year. It can be observed the time of starting to form edges, activeness and passiveness behaviors but we cannot describe a general discourse about it. For further investigation, the effects of hub development on the growth potential can be the subject of detailed analysis (Grove and O'Kelly, 1986).

When we observed the hub developments; we see that some hubs who demonstrate atypical behaviors, even if we group hubs by their joining the network time and path development as seen in comparative analysis table shortly, Table 4.26. It is difficult to state a common point, so we cannot have an idea for further with any specific prediction.

For instances, at the outset one can argue that the Figure 4.1 does not exhibit any particular pattern for three hubs except their typical step functions alike behavior. The maximum hub, whose id is 1064632, starts to form edges in middles of year and has steep line; he increasing dramatically. The hub 1300836 starts to form edges at the ends of year with a big jump, then she has stability and has increasing line. The hub 1083936 starts to from edges in the beginnings of the year with a step, then he became a sleep node and active node towards end of year and has increasing line. So, we observed that starting times and behaviors are different, they have steps, sometimes small sometimes big, but almost all of them have lots of steps. Then, we have observations that the hubs become more active towards end of year in common.

We present five male physicians in Figure 4.2. Maybe they seems similar firstly but the maximum hub 1064632 and hub 1086412 have different behaviors from the others, 1064632 constantly increasing and 1086412 has a step then going straight, also both of them acting towards end of year. However the other three hubs; 1066723, 967924 and 186210 join the network beginnings of the year, but they sleep for a while then become active and have slight changes towards end of the year.

The six female visitors displaying on Figure 4.3. They become active after week the 28 in general. The hub 875105 joins the network on the 3rd week but he sleeps until week the 28, too. We have not got any contextual variables about the hubs except their roles and genders so we do not know the reason of hubs becoming more active towards end of the year. Three female visitors have similar lines; hubs 1135619, 655172 and 875105 becoming active towards end of the year and increasing slightly. The hubs 1300836, 312045 and 1273971 joins with big steps to the network towards end of the year, the most big jump belongs to hub 1300836, then they sleeps for a while after that they have monotonic increase as stated in comparative analysis Table 4.26, orange rows present female visitors.

We represent the six male visitors, which have apparent steps, in Figure 4.4. All of them become active towards end of the year and they have steps distinctly. They have monotonic increases with jumps and sleeps. However, the hub 1310608 present atipic behavior; he has steep line, continuously increasing and never sleep, he has 46 edges in ten weeks. If it is investigated the hub development as time maybe it can be reached the potential of hub growth for another study. These six male visitors colored as yellow row in comparative analysis Table 4.26.

We present five male visitors which start to form edges at the beginnings of the year and sleep for a while then they continues to have interactions in Figure 4.5. The hubs 1083936 and 745444 are become active towards end of year and have monotonic increase. The other three hubs starts with small steps then have stability sometimes but have slightly changes in general, they progressing in small increments. These five male visitors colored gray in comparative analysis Table 4.26.

5.2 Implications for Practice

In the recent years, the customer loyalty has an important place in marketing literature as can be used decision-making. Network managers or platform owners can use network measures for practice. The value of network measures for platforms may be of interest to managers or providers (Sharma et al., 2014). The basis of our study depends on providing additional analysis to traditional computing by an in-depth analysis.

Habits are hard to break. If we think the online platform as an organization or a company and members or nodes as a customer, we can observe a loyalty relation between customers and organization (Reichheld, 1992). Loyal customers believe the products and services acquired from their supplier are preferable to those of the competition because they think that offering your organization is their finest opportunity even they faced with a different choice. Measuring loyalty is to measure the power of the relationship between the organization and its customer, continues and repeating behaviors are indications for customer loyalty (Dick and Basu, 1994).

If you make your success continuous as a company, you need to provide the continuity of customer (Reichheld, 1992). That is why the companies make loyalty cards, they are not satisfied by getting all kinds of information of customers, but also examine the shopping habits and patterns continuously. They investigate that which month or which products do you buying more, how much do you sensitive the discount, what time of day do you spend more money and on which product groups mostly, which days and weeks of the month your shopping is more, what is your average purchase amount, how often do you do the shopping, when did you buy something at last time, your shopping behavior has an increasing or decreasing trend in months or years, and so forth. In short, you are cared by company as much as you do not feel before probably. Many company want to tie to them all the time according to the gathered information from you or customer group with the help of loyalty cards or even by individual customer-oriented campaigns. It is quite wisely, you can be out of risk with so much information. After all, the resources are limited and the time goes by quickly, the trial chance is very little for organizations, so they need detailed analysis and right decisions (Chau and Xu, 2012).

As above example, we examine the hub behaviors in detail as we explained before in our study with the time periods and habits of hubs particularly. Hub development can be an encouraging indicator of how well the platform is received by target users. Basic stages of its development can give indication of the customer loyalty. Starting with its inception stages of hubs the platform manager can monitor its development that can be help in management and decision-making (Mehmet Aydın, 2015). For example, platform managers can be aware of customer priorities, which attributes have contributions on being a member of platform and resume the relations. In this regard, platform owners can be observe how the network growth over hubs and how long it will take to be a hub in the platform with the help of the detailed analysis of hubs. Additionally, important changes in hub development such as sudden steps can be early warnings of certain behaviors that need a deeply analysis of what causes these changes. Platform managers and sponsors can use the hub development analysis as a novel metric monitoring the growth of network, so the platform. Platform value is stated with significance of interactions of members going over hubs to evaluate their contributions to the network (Gneiser et al., 2012). The other practical result of monitoring hub development is to see the effects of platform feature and design decisions and changes on platform performance and value (Wijnhoven and Kraaijenbrink, 2008). These outcomes are significant for organizations actively promoting and managing the online platforms. "*Whatever the underlying reason (their common best interests) for selecting to use the product is, the company can be considered to achieve its goal that they have created (virtual) customers loyal to them. That is to their product/service, who spent a considerable amount of time interacting with it. Of course, the real customer is not people who have been attracted to the service but the people who would pay for the amount of time members spend interacting with the product (Steinfield et al., 2008)." (Mehmet Aydın, 2015)*

Chapter 6

Conclusion

As the importance of social and/or information networks is greatly increasing in our individual and social life, one needs to analyse their effects on our life. One particular emerging scientific field called network science is committed to examine the very idea of network phenomena from such research domain as management, computer science, math, sociology, physics. This research is attempted to answer the following key research question: What are the basic measures one can use for better understand hub development? If and what particular behaviours can be discerned for hub development in a health information platform? What are basic characteristics of hubs that contribute to network growth? What are the implications of such answers to these questions for platform managers? We adopt network science perspective to guide our research for an empirical data analysis. Thus, we analyse the real-world data set of health platform, which provide us data-driven insights to explore the very idea of hub development (Dodds et al., 2003).

One of the typical characteristics of real-world network is that low-degree nodes are connected to each other through the hubs, which has been examined extensively in social science, but, to the best of our knowledge, not in exclusively in computer science. We examined the development of hubs belongs the online information health platform which is a real-world network and specified and reveal the characteristic features of them. We tried to understand how the degree of each hub is increased individually, what the effects of these hubs on the network growth or if and how attributes of hubs can contribute to the network growth (Grove and O'Kelly, 1986). We employ assortativity / dissassortativity as a sentising concept to explore hub feature in this given real-world network. We examine, hub lifecycle in terms of hub emergence that is when the nodes start to be a hub, and is it possible being a hub for a node if it joins to network through the end of year.

It can be clearly seen that the contributions of the network science to management science can be substantial if one can associate the findings with business intelligence (Johnson et al., 2014). We argue that hub development in fact can provide complementary insights to typical customer value metrics. This addition is suggested as customer loyalty based on hub development. The scientific data, which helps to increase the productivity of a company taken the right decision at the time exhibiting the all details of it, provided by the network science will be a kind of microscope as a tool in the hands of the senior management (Aydin and Perdahci, 2013). The future researches in network science and hub development analysis can help to measure the realization, progress and continuity of the business.

In our study, there was not the knowledge of contextual variables belong to hubs except role and gender attributes. For instances, it was not known the expertise area of physicians. Such as limitations has restricted us to more detailed investigation. Also, Gephi allows us the opportunity to study according to the degree of nodes but not to domain specifics. For further investigation, it can be studied on the effects of hub development on the growth potential in detail with a different tool, which has more capacity about analyzing network and network members with all key specifications of them, such as R programme (Kolaczyk and Csárdi, 2014).

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Curriculum Vitae

Şeyma Çalışan Özyurt was born in July 14th, 1987, in Ankara. She received her BS in Computer Science Department of Bilgi University in 2012. She has been working in the Information Technology Department of Eyup Municipality since December, 2012.