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Abstract - The academic mobility is one of key factors that enable the globalization of research and education. In this paper we study the network of ERASMUS staff and student exchange agreements between academic institutions involved in FETCH – a big European project oriented towards future education and training in computer science. The structure of the network was investigated relying on standard metrics and techniques of social network analysis. Obtained results indicate that the network is in a mature phase of the development in which none of the institutions has a critical role to the overall connectedness of the network. Additionally, the network has a clear core-periphery structure with an active core and mostly inactive periphery.

I. INTRODUCTION

Over the past years, we have witnessed a continuous trend of enlargement of number of exchanges for students and lecturers between European countries, under various exchange programs, and especially under the Erasmus programme. The main goal of the Erasmus programme is to promote and facilitate mobility in higher education. The programme was inaugurated in 1987, and today it is the largest programme for the academic mobility in Europe: it has enabled more than 2 million students to temporary study in another European county [5], [6]. Moreover, there are a large number of signed bilateral ERASMUS agreements between European Universities for exchange of both students and lecturers. These agreements, and therefore exchanges, help not only as a tool for personal development and introduction to other cultures, but also improve future chances for easier and better opportunities for employability, especially for students from central and eastern European countries [15]. In turn, this leads to improved chances for future social cohesion and economic development not only at local and regional, but also at the European level, promoting the further development of labor market.

In this paper we study a ERASMUS staff and student mobility network formed by academic institutions participating in the FETCH project (Future Education and Training in Computing: How to support learning at anytime anywhere) [4]. The project encompasses 67 universities and companies from 35 European countries. The principal objective of the project is to raise the quality of computing education with novel methodologies, didactical theories, learning models and innovative technologies. More specifically, the main goals of the project are the development of strategic and evaluation frameworks for modern computing education and training, preparation of recommendations for future digital curricula, and the development of theories and models for social media education. The project is divided into 9 working packages where one of them, Work Package 8 (WP8), is partially devoted to the creation of a European Erasmus network for student and lecturer exchange in the field of computing education. The main goal of this paper is to evaluate the current state of the ERASMUS mobility network among institutions participating in WP8.

The rest of the paper is structured as follows. The second section gives the insight into related works performed on similar topics. The third section explains the data set used to extract the network. The methods used in the analysis of the network are presented in the subsequent, fourth section of the paper. The obtained results are presented and discussed in the fifth section. The last section concludes this article and outlines directions for possible future research work.

II. RELATED WORK

Analysis of topologies of real-world networks, and in particular Erasmus networks of student exchange has been performed in the past. For example, one of the interesting papers dealing with this subject is [3]. The authors constructed a directed and weighted graph of Erasmus collaboration among universities determined by Erasmus student mobility realized in 2003. Then they analyzed the structure of its non-directed and non-weighted (NDNW) projection. The results of the analysis showed that the NDNW projection of the network contains a giant connected component exhibiting the small-world property. The degree distribution analysis revealed that the NDNW projection of the network does not belong to the class of scale-free networks, but to the class of random graphs with exponential degree distributions. Finally, the authors showed that the configuration model of random networks can reproduce and explain empirically observed structural characteristics of the network.

Another important article giving valuable insight into student mobilities is [16]. This article tries to analyze interaction patterns of Erasmus students. Among other things, authors conclude that "…our study shows that students' networks abroad are already formed before actual departure." Also, authors claim that they "…provide empirical evidence that institutional as well as group practices encourage or impede interaction between exchange and local students."

The fact and consequences of "…studying abroad can directly or indirectly influence students' career paths and potentially offers additional job opportunities…" is investigated in [1]. Authors were using the similar method as the one used in this article, and claim that "…with the help of an advanced network analytic method – the island approach – we were actually able to determine the groups of institutions in the network which collaborate most extensively inside of Erasmus student exchange programme."

A very interesting conclusion concerning the similar researched subject is given in [14]. Namely, the author discovered that "…although studying abroad led to increased socializing with other Europeans, contact with host country students remained limited." Considering the so-called "European identity" and the influence of studying abroad on it, there are two conclusions given in a mentioned article:

- ERASMUS does not strengthen students' European identity, on the contrary, it can have an adverse effect on it, and
- increased socializing with Europeans has a positive, though modest, impact on European identity.

As a continuation of this practical kind of research of mobilities induced by ERASMUS programmes, it is also important to mention article [11] that investigates "...the factors influencing these student flows." As might be expected, "…country size, cost of living, distance, educational background, university quality, the host country language and climate are all found to be significant determinants." Yet, the main finding that authors mention is that "…despite the financial support granted by the EU and other institutions, the cost of living differences and distance are still relevant when explaining European student mobility (ESM) flows." Based on this finding, authors conclude that "…it is evident that more economic support could enhance ESM."

Finally, research on the similar subject is often conducted within one country. An example of research of this kind can be found in [10]. The paper "…describes two projects based on the issue of virtual mobility…." where "…special attention is devoted to the efficiency of virtual mobility." One of the interesting conclusions authors gave is that "…beside gained knowledge they enrich their students' lives with worthy experience collected by their study in different cultural environment."

Contrary to previously mentioned studies, in this paper we analyze an Erasmus mobility network encompassing institutions involved in a large, but specific project related to computer science education. The primary goal of the study is to examine whether the project itself imposed a stimulating environment for establishing and realizing Erasmus exchanges among participating institutions. Therefore, we investigate the structure of the network using social network analysis methods in order to assess its cohesiveness, compactness and robustness. Additionally, we analyze the structure of active links in the network in order to identify key institutions in the actual realization of established Erasmus agreements.

III. DATA SET

This study is based on the data about ERASMUS staff and student exchange agreements reported from 37 institutions involved in the Work Package 8 (WP8) of the FETCH project. The members of the project involved in activities of WP8 were asked to deliver the following information for their institutions:

1. the list of institutions with whom they have settled ERASMUS exchange agreements in computer science domain (including both FETCH partners and institutions that do not participate in the FETCH project),
2. the number of student exchange agreements and the number of staff exchange agreements per each ERASMUS partner, and
3. the numbers of realized student and staff exchange agreements for the last three school years per each ERASMUS partner.

The FETCH institutions who responded to the survey are from the following European countries: Albania (1 institution), Austria (1), Bulgaria (8), Croatia (1), Cyprus (1), Czech Republic (1), Denmark (1), Estonia (1), Finland (1), Germany (1), Greece (1), Island (1), Italy (3), Liechtenstein (1), Lithuania (1), Luxembourg (1), FYR Macedonia (1), Portugal (1), Romania (1), Serbia (1), Slovakia (1), Spain (1), Sweden (1), Turkey (3) and UK (2).

IV. METHODS

From the collected data we reconstructed the FETCH network of ERASMUS bilateral agreements. The nodes of the network correspond to the institutions that responded to the data collection survey. Two institutions are connected in the network if they signed one or more student or staff ERASMUS exchange agreements. The nodes in the network are connected by undirected links since signed ERASMUS exchange agreements between the institutions participating in the FETCH project are bilateral. The link between A and B is considered active if there were student or staff exchanges between *A* and *B* in the last three school years. Consequently, an institution in the network is considered active if the corresponding node in the network is incident to at least one active link.

Standard techniques and metrics used in social network analysis are employed to analyze the FETCH network of ERASMUS bilateral agreements. The structure of the network is investigated using connected component analysis and *k*-core decomposition [8], [9], [13]. A node is reachable from some other node if there is a path connecting these two nodes. A connected component of a network is a maximal set of mutually reachable nodes. If a component encompasses a vast majority of nodes then we say that the network has a giant connected component [9]. Connected components can be identified using classical graph traversal algorithms such as BFS (breadth first search) and DFS (depth first search). The absence of a giant connected component in the FETCH network of ERASMUS agreements indicates that the mobility network of institutions involved in the FETCH project is still in an early phase of its development and that it consists of several, small independent clusters among which there are no mobility flows. A node is called articulation point if its removal from the network increases the number of connected components. A giant connected component can be considered robust if there is no articulation point whose removal disintegrates the component into several non-giant connected components. A robust giant connected component implies that none of the institutions in the network has the critical role to the overall connectedness of the network.

The degree of a node in the network is the number of links incident to the node. In our case the degree of a node is also equal to the number of other nodes to which the node is directly connected since the network does not contain parallel links (different links connecting the same pair of nodes). A node is called isolated if its degree is equal to zero. Isolated nodes in the analyzed network actually represent FETCH institutions that have not established ERASMUS exchange agreements with other FETCH partners.

To quantify compactness of connected components and their connected sub-networks we rely on two network statistics: characteristic path length and diameter [8]. The distance between two nodes is defined as the length of the shortest path connecting them. The characteristic path length is the average distance of all pairs of nodes in the component, i.e.

$$l = \frac{N(N-1)}{2} \sum_{i,j \in V, i \neq j} d(i,j),$$

where V denotes the set of nodes in component, N their number and $d(i, j)$ is the distance between nodes i and j. On the other hand, the diameter of the component is the maximal distance between nodes, i.e.

$$D = \max_{i,j \in V} d(i,j).$$

The transitivity of links in the network is measured by the clustering coefficient [17]. The clustering coefficient is a probability that two neighbors of a randomly selected node are neighbors among themselves, or, equivalently the density of links among neighbors of a randomly selected node. More formally, the clustering coefficient of node i can be expressed as

$$C(i) = \frac{2}{k_i(k_i - 1)} \left| \left\{ e_{jk} : j,k \in N_i,\ e_{jk} \in E \right\} \right|,$$

where E denotes the set of links in the network, k_i is the degree of node i and N_i is the set of nodes connected to i.

Node centrality metrics can be employed to identify the most important nodes in a network considering its structure. In our analysis we employ betweenness, closeness and eigenvector centrality measures [9] to rank and identify the most important institutions within the network. The betweenness centrality of a node z, denoted by $BET(z)$, is the extent to which z is located on the shortest paths connecting two arbitrary nodes different than z, i.e.

$$BET(z) = \sum_{\substack{x,y \in V \\ x \neq y \neq z}} \frac{\sigma(x,y,z)}{\sigma(x,y)},$$

where $\sigma(x, y)$ denotes the number of shortest paths connecting x and y and $\sigma(x, y, z)$ is the number of shortest paths between x and y that pass through z. The closeness centrality of z, denoted by CLO(z) is inversely proportional to the cumulative distance between z and other nodes in the network, i.e.

$$CLO(z) = \left(\sum_{x \in V, x \neq z} d(x,z) \right)^{-1}.$$

The intuition behind the eigenvector centrality measure is that a node can be considered important if it is surrounded by important nodes. This means that the eigenvector centrality of z, denoted by EV(z), is proportional to the sum of eigenvector centralities of its neighbors, i.e.

$$EV(z) = c \sum_{x \in N(z)} EV(x),$$

where c is a constant and $N(z)$ is the set of neighbors of z.

A k-core of a network is a maximal sub-network of the network such that each node in the sub-network has degree higher or equal to k [13]. A k-core therefore can be obtained by recursively deleting all nodes whose degree is less than k until all nodes in the remaining network have degree at least k. A node has shell index k if it belong to some k-core of the network, but not to a (k+1)-core. It is important to emphasize that the shell index is not the same as the degree of a node. For example, a node with a high degree connected to nodes of degree 1 has shell index equal to 1. The maximal core of a network encompasses nodes with the highest value of the shell index. If the maximal core is a relatively large, densely connected sub-network then we can conclude that the network possesses a core-periphery structure [11]. The existence of a core-periphery structure in the FETCH network of ERASMUS agreements implies that the network is organized around a subset of institutions that have the crucial role for the development and cohesiveness of the whole network.

To identify cohesive clusters in the network we use the Louvain method for community detection [1]. This method is based on a greedy multi-resolution approach to maximize the Girvan-Newman modularity measure [1], [9] starting from the partition in which all nodes are put in different communities. When the modularity is optimized locally the algorithm builds the network of communities and repeats the local optimization step until no increase of modularity is possible.

The network encompassing only active links can be studied as a directed graph according to the actual realization of Erasmus exchange agreements. In our analysis we use the HITS link analysis algorithm [7] to identify the most important hub and authority institutions in realized Erasmus agreements. In our case, important hubs correspond to institutions having a high out-going mobility to the most important authorities, while important authorities are institutions with a high in-coming mobility from the most important hubs. The HITS algorithm assigns two mutually recursive scores, hub and authority scores, to each node in the network. The authority score of a node z is equal to the sum of hubs scores of nodes pointing to z, while the hub score of z is the sum of authority scores of nodes referenced by z.

V. NETWORK ANALYSIS - RESULTS AND DISCUSSION

Institutions involved in the FETCH project which reported data about ERASMUS exchange agreements established 2138 student and 930 staff exchange agreements in total (with both FETCH and NON-FETCH institutions). Approximately 18% of student exchange agreements and 28% of staff exchange agreements are agreements between FETCH partners. An average institution involved in the FETCH project established student/staff agreements with approximately 5 FETCH and 16 NON-FETCH partners. The average number of ERASMUS student exchange agreements among FETCH partners is equal to 10.65, while the average number of ERASMUS staff exchange agreements is slightly lower and it is equal to 7.08.

The FETCH network of ERASMUS bilateral agreements consists of 37 nodes (FETCH institutions) and 89 links (agreements between FETCH institutions). The connected component analysis revealed that the network contains 4 connected components: 3 isolated nodes and 1 giant connected component encompassing the rest of the nodes (see Figure 1 (a)). Isolated nodes represent FETCH institutions that have not established ERASMUS bilateral agreements with other FETCH partners. However, all 3 isolated nodes in the network represent institutions that have ERASMUS student and staff exchange agreements with NON-FETCH institutions. On the other hand, the existence of the giant connected component implies that the vast majority of institutions are either directly or indirectly connected in the network, further suggesting that the mobility network among FETCH institutions is in a mature stage of the development and that it transcends regional boundaries.

The diameter of the giant connected component is equal to 4, while the characteristic path length is equal to 2,12. This means that the network possesses the small-world property – the average distance between randomly selected nodes is significantly smaller than the number of nodes in the network. The network has a high clustering coefficient (probability that two neighbors of a randomly selected node are neighbors among themselves) equal to 0,439. The clustering coefficient of a comparable random graph is equal to $C_{rand} = 2L/N(N-1) = 0.13$, where N and L denote the number of nodes and links in the network, respectively. Since empirically observed clustering coefficient is three times higher it can be concluded that the network exhibits the small-world phenomenon in the Watts-Strogatz sense [17].

The giant connected component of the network contains 5 articulation points – nodes whose removal from the network disintegrates the giant connected component into two or more connected components. The removal of each articulation point breaks the giant connected component into exactly two components: one isolated node and one non-trivial component containing the rest of the nodes. This means that the network still has a giant connected component after an articulation point is removed. Therefore, we can conclude that the giant connected component is highly robust: there are no FETCH institutions whose existence is critical to the overall connectedness of the network. In other words, the network is not built around a small number of institutions that keep a large number of other institutions connected.

The k-core decomposition of the giant connected component revealed that the maximal shell index of the nodes is equal to 4. The maximal core of the network (4-core) is shown in Figure 1 (b). It consists of 17 nodes (46% of the total number) and 53 links (60% of the total number). The diameter of the maximal core is equal to 2 which implies that each two nodes from the maximal core are either directly connected or indirectly connected via common neighbors that also belong to the maximal core. It can be observed that the maximal core is a densely connected sub-network. Therefore, we can conclude that the network has a core-periphery structure where highly connected nodes in the network form a compact, densely connected core, while loosely connected nodes from periphery are attached to nodes from the core.

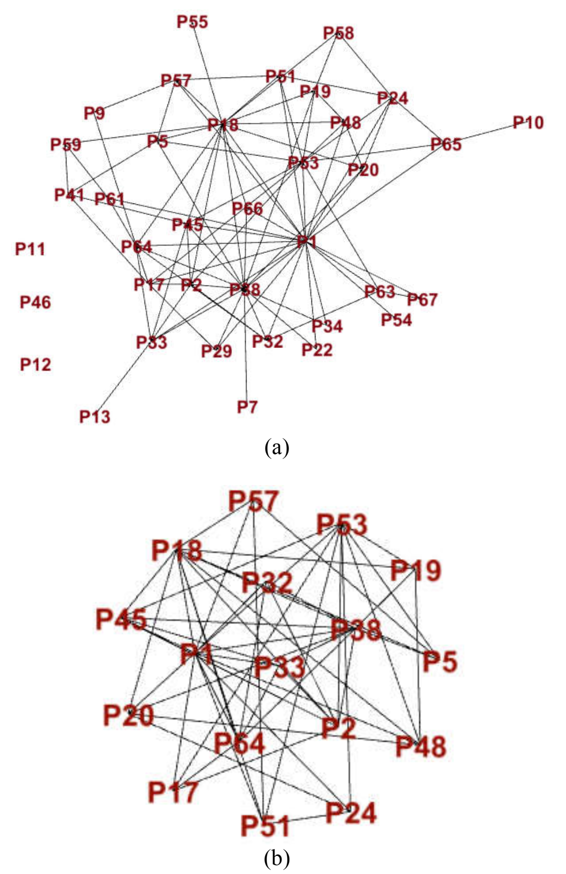

Figure 1. The giant connected component of the network (a) and the maximal core (4-core) of the giant connected component (b).

We used three different node centrality metrics to rank and identify the most important institutions in the network. The top five institutions having the highest rank by betweenness, closeness and eigenvector centrality measures are shown in Table 1. It can be noticed that four institutions can be considered as the most important by all three considered node centrality metrics. Those institutions are P1 (University of Rousse, Bulgaria), P18

(Czech Technical University in Prague), P38 (Vilnius University, Lithuania, and P53 (Linnaeus University, Sweden). Additionally, P33 (University of Pavia, Italy) and P45 (University of Coimbra, Portugal) are among the top 5 highest ranked institutions according to betweenness and eigenvector centrality, respectively.

TABLE I. THE TOP FIVE INSTITUTIONS IN THE NETWORK ACCORDING TO DIFFERENT CENTRALITY MEASURES (BET – BETWEENESS CENTRALITY, CLO – CLOSENESS CENTRALITY, EV – EIGENVECTOR CENTRALITY).

BET		CLO		EV	
P1	220.26	P1	0.75	P1	1.00
P18	96.55	P38	0.63	P38	0.76
P38	84.31	P18	0.62	P18	0.75
P53	34.14	P64	0.56	P53	0.57
P33	33.33	P53	0.55	P45	0.51

We identified communities in the giant connected component using the Louvain method. The Girvan-Newman modularity of the obtained partition is equal to 0.256 which means that the network exhibits a moderately strong community structure. The partition of the network into communities is shown in Figure 2 and it can be seen that it consists of 2 large clusters each of them encompassing 12 institutions and 2 relatively small clusters (one of them consists of 6 and another of 4 nodes). The first large community is organized around P1 (University of Rousse, Bulgaria) and P38 (Vilnius University, Lithuania). The best connected nodes in the second large community are P18 (Czech Technical University in Prague) and P53 (Linnaeus University, Sweden). In other words, the two largest communities are organized around the most central nodes in the network (see Table 1). A common characteristic of two small

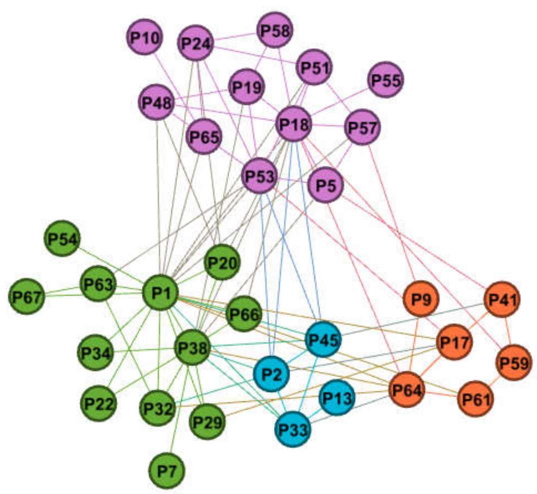

Figure 2. Communities in the giant component

clusters is that they do not contain two institutions from the same country: the first small cluster encompasses institutions from Bulgaria, Cyprus, Luxembourg, Lichenstein and Turkey, while institutions from Austria, Bulgaria, Italy and Portugal belong to the second small cluster.

Tables 2 and 3 show the summary statistics of realized student and staff exchange agreements, respectively, for the last three school years. A link in the network is considered active if there were students or staff exchanges between connected FETCH institutions during the aforementioned time period. Not all links in the network were active implying that there are unrealized Erasmus agreements among FETCH institutions. The number of active links is equal to 43 (48.31% of all links in the network) and they are shown in Figure 3.

TABLE II. THE SUMMARY STATISTICS OF REALIZED STUDENT EXCHANGE AGREEMENTS.

Year	Total	Between FETCH institutions	With non-FETCH institutions
2013/12	377	103	274
2014/15	875	63	812
2015/16	447	48	399
Sum	**1699**	**214 (12.6%)**	**1485 (87.4%)**

TABLE III. THE SUMMARY STATISTICS OF REALIZED STAFF EXCHANGE AGREEMENTS.

Year	Total	Between FETCH institutions	With non-FETCH institutions
2013/12	166	29	137
2014/15	181	36	145
2015/16	125	22	103
Sum	**472**	**87 (18.4%)**	**385 (81.6%)**

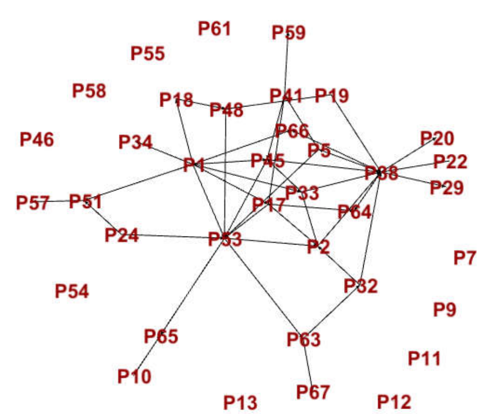

Figure 3. The network without inactive links.

The network of active links reflecting realized student and staff mobility among institutions participating in the FETCH project can be analyzed as a directed graph. We applied HITS link analysis algorithm to this network in order to determine the most prominent hubs and authorities in mobility flows among FETCH partners. The results are summarized in Table 4. The institution with the largest hub score is actually the leading institution of the FETCH project (P1 – University of Rousse, Bulgaria). The institution exhibiting the largest authority score is P53 (Linnaeus University, Sweden). Also it is interesting to notice that the most important hubs are institutions from different countries (Bulgaria, Lithuania, Cyprus, Italy, and Luxembourg). The same holds for the most important authorities which are institution from Sweeden, Portugal, Turkey, Cyprus and Spain. Therefore, we can conclude that the most important institutions in the Erasmus student and staff mobility flows among FETCH institutions are not regionally localized.

TABLE IV. THE TOP FIVE HUBS AND AUTHORITIES IN THE NETWORK OF ACTIVE LINKS.

Hubs		**Authorities**	
P1	0.70	P53	0.47
P38	0.40	P45	0.46
P17	0.26	P66	0.32
P33	0.26	P17	0.28
P41	0.24	P51	0.27

VI. CONCLUSIONS AND FUTURE WORK

In this paper we studied the ERASMUS mobility network formed by the institutions involved in the FETCH project. The network was reconstructed from the data about student and staff ERASMUS exchange agreements reported by 37 institutions from 25 European countries. Techniques commonly used in social network analysis were employed to investigate the structure of the network. The analysis of connected components in the network showed that the network is not in an early stage of the development and that it transcends regional boundaries. Moreover, the network is a compact, small-world in which none of the institutions has a critical role to the overall connectedness of the network. The k-core decomposition of the network revealed that the network has a core-periphery structure with compact, densely connected core composed of active institutions that realize established ERASMUS agreements with other FETCH partners. On the other hand, the periphery of the network is mostly inactive indicating that there is a huge space to improve current mobility flows among institutions involved in the FETCH project.

In this work we have shown that techniques used in social network analysis can be beneficial to the understanding of the structure of academic mobility flows. Therefore, in our future work we plan to investigate academic mobility at a larger scale that is not restricted to institutions involved in a particular scientific project. Also, we will model and analyze mobility networks as temporal, spatial, directed and weighted graphs in order to (1) investigate spatial and temporal patterns of academic mobility, (2) analyze the strength of academic mobility considering spatial and temporal aspect of the network, and (3) address issues related to the incoming and outgoing academic mobility.

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REFERENCES

[1] Blondel, V., Guillaume, J.-P., Lambiotte, R., Lefebvre, E., Fast unfolding of communities in large networks, 2008 (10), P10008, 2008.

[2] Breznik, K., Gologranc, G., Erasmus Mobility On The Institutional Level, International Conference “Management, Knowledge and Learning”, Portorož, Slovenia, 2014.

[3] Derzsi, A., Derzsy, N., Káptalan, E., Néda, Z. Topology of the Erasmus student mobility network, Physica A, Vol. 390, pp. 2601–2610, 2011.

[4] ETN FETCH – Future Education and Training in Computing: How to support learning at anytime anywhere. Official website of the project: http://fetch.ecs.uni-ruse.bg/?cmd=gsIndex (accessed July 17th 2016)

[5] Gonzales, C. R., Mesanza, R. C, Mariel P. The determinants of international student mobility flows: an empirical study on the Erasmus programme. Higher Education, 62(4), pp. 413-430, 2011.

[6] Janson, K., Schomburg, H., Teichler, U. The Professional Value of ERASMUS Mobility – The Impact of International Experience on Former Students’ and on Teachers’ Careers. Bonn: Lemmens Medien GmbH, 2009.

[7] Kleinberg, J., Authoritative sources in a hyperlinked environment. Journal of the ACM. 46 (5): 604–632, 1999.

[8] Newman, M. E. J. The Structure and Function of Complex Networks. SIAM Review, 45(2), pp. 167-256, 2003

[9] Newman, M. E. J. Networks: An Introduction. Oxford University Press, 2010.

[10] Poulová, P., Černá, M., Svobodová, L. University Network – Efficiency of Virtual Mobility, 5th WSEAS/IASME International Conference on Educational Technologies (EDUTE' 09),

[11] Rodríguez González, C., Bustillo Mesanza, R. & Mariel, P. The determinants of international student mobility flows: an empirical study on the Erasmus programme, High Educ, 62: 413. doi:10.1007/s10734-010-9396-5, 2011.

[12] Rombach, M. P., Porter, M. A., Fowler, J. H., and Mucha, P. J. Core-periphery structures in networks. SIAM Journal of Applied Mathematics, 74(1), pp. 167-190, 2014.

[13] Seidman, S. B. Network structure and minimum degree. Social Networks, 5, pp. 269-287, 1984.

[14] Sigalas, E. Cross-border mobility and European identity: The effectiveness of intergroup contact during the ERASMUS year abroad, European Union Politics, 11(2) 241–265, DOI: 10.1177/1465116510363656, 2010.

[15] Teichler, U., Jason, K. The Professional Value of Temporary Study in Another European Country: Employment and Work of Former ERASMUS Students. Journal of Studies in International Education, 11(3), pp. 486-495, 2007.

[16] Van Mol, C., Michielsen, J. The Reconstruction of a Social Network Abroad. An Analysis of the Interaction Patterns of Erasmus Students, Mobilities Vol. 10, Iss. 3, pp. 423-444, 2015

[17] Watts, D. J., Strogatz, S. H. Collective dynamics of “small-world” networks. Nature, 393, pp. 440-442, 1998.