Social Network Analysis as a Tool to Evaluate the Effectiveness of EC Funded Networks of Excellence: The Case of DEMO-net

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Abstract

The European Commission, through its Framework Programme aims to stimulate the development of sustained collaborative research networks across Europe. Social network analysis (SNA) has previously been used to evaluate collaboration between projects at a European level. In this study SNA was used to evaluate the nature of the relationship between researchers at network startup, roles subsequently allocated to them, and network configuration. A correlation was found between centrality at startup and subsequent role allocation. Indegree/outdegree analysis provided some indication of this but greater insight was found from examining network partitions and n-cliques.

1 Introduction

The FP (Framework Programme) is the main vehicle for funding research across Europe. The European Commission (EC) is responsible for drawing up the research framework on an overlapping quinquennial cycle. Each FP is debated and adopted by the European Parliament. The FPs have a history of delivering good scientific and technical results but have tended not to result in substantial and sustained research coherence across the EU as a whole (http://ec.europa.eu/research/fp6/pdf/faq_en.pdf). The sixth framework (FP6) running from 2003 to 2008 aimed to address this weakness by introducing new instruments (or cooperative research structures) with the aim of funding coherent programmes of collaborative research activity rather than multiple independent projects. One of these new research instruments is the Network of Excellence (NoE). NoEs were designed to integrate the research activities of partners and create virtual centres of excellence (http://ec.europa.eu/research/fp6/pdf/fp6-in-brief_en.pdf). A key aim of NoEs is to develop sustainable structural change across the research network, thus ensuring a legacy of a stronger and more integrated network of research partners at the end of the project.

One of the NoEs funded under FP6 was DEMO-net: The eParticipation Network (FP6-2004-27219) whose aims include strengthening "scientific, technological and social research excellence in eParticipation by integrating the research capacities of individuals and organisations spread across Europe" (http://www.demo-net.org/demo/aboutdemonet). DEMO-net is structured in a similar way to the majority of EC projects. That is, it consists of a number of Work Packages (WPs), with each WP having responsibility for one or more Tasks. Each WP has a Work Package Leader (WPL), while the responsibility for Tasks may be devolved to others (Task Leaders (TL)). Work Package Leaders may also be Task Leaders and an individual may be a leader of one or more Tasks and/or Work Packages. Each Work Package and Task also involves a number of other active researchers. A total of 78 researchers (the population used for the network analysis) were in the network at the start of DEMO-net. Phase 1 of the DEMO-net project ran from late 2005 to March 2007 and consisted of 7 WPs and 43 Tasks. Phase 2 will also be broken into 7 (different) WPs, to be led by 12 individuals; 21 individuals have been nominated as leaders of its 37 tasks.

Given the focus within DEMO-net of developing an integrated network for research in eParticipation it is entirely appropriate that the issue of how to evaluate and measure the growth of the network was an integral part of the project plan. This paper examines the relationships between members of DEMO-net at the beginning of Phase 1, and examines how they are reflected in the roles that have been assigned in Phase 2.

2 Rationale for using SNA to evaluate DEMO-net

Social Network Analysis (SNA) is increasingly being used as a technique to study the structure, cohesiveness and growth of diverse types of networks such as online learning communities, patient/carer communities and terrorist groups and the performance of organisations and teams. An extensive corpus of literature exists which covers these areas and although much of it is relevant to our work there is no attempt to replicate or review it within this paper. Our focus here is on research networks. Within the area of research

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and knowledge transfer SNA has been used to map the structure and scope of specific research domains (eg Reid and Chen [14]), to track knowledge diffusion (eg Busch, Richards and Dampney [6]), and to examine behavioural aspects of citation networks (eg Barábasi et al [1]; McKechnie, Goodall and Julien [12]; Newman [13]). Some authors have attempted to draw conclusions about the relationship between research activity networks and the social relationships that exist in those networks (eg White, Wellman and Nazer [19]). SNA is, of course, just one approach to studying research networks, it can be usefully complemented by or corroborated with results from author citation analysis (Davenport and Cronin [8]), acknowledgement analysis (Cronin [7]), content analysis (Krippendorf [10]) and measuring research output.

Within the context of the EC Framework Programme, Besussi [2] has used SNA to map the spatial (geographic) dimensions of the Networks of Excellence within FP6. Whilst Wagner et al [18] used SNA to evaluate the effect of the new FP6 research instruments on IST (information society technologies) research, with a particular focus on the changing dimensions of pan-European collaboration. Malerba, Vonortas, Breschi and Cassi [11] use SNA as an analytic tool to argue that FP6 "IST-RTD [Information Society Research and Technological Development] Programmes have a positive role in attracting key actors, in creating and increasing network connectivity, and in generating and diffusing new knowledge". However, prior to the emergence of NoEs Breshi and Cusmano [5] used SNA to explore the problem of what they call 'oligarchic cores' in EC research projects, where the power base is held by a few strong players. They offer cautionary observations about the potential for these to exist in NoEs at the expense of the development of connectivity and involvement of peripheral players. Our research extends themes addressed in this body of literature.

One of the key objectives of DEMO-net is to "Ensure growth and sustainability of the network by encouraging and motivating organisations and researchers in areas relevant to eParticipation to join in the activities of DEMO-net" (Tambouris et al [16]). The effectiveness of DEMO-net in relation to this objective and the overall objectives for NoEs in achieving a legacy of strong and integrated network can be explored by examining:

- changes to the density of the network over time
- changes to the structure of the network over time (including possible changes to partner and geographic allegencies)
- the extent and nature of the development of the collaborative research input and output activities.

Given the use of SNA to examine networks in a range of research and knowledge transfer contexts, and across FP6 in particular, it is entirely appropriate that this analytic technique has been selected to support the analysis and evaluation of the effectiveness of the DEMO-net research community.

The DEMO-net SNA evaluation is being undertaken at three distinct stages. This paper describes the work undertaken at the first stage.

Stage 1: Mapping and evaluating the structure and research activity of the DEMO-net community at the start-up of the Network of Excellence.

Stage 2: Midpoint review of the growth of research activity to identify changing structures and relationships with a view to identifying areas of research activities that are being or can be further enhanced or facilitated through the DEMO-net consortium.

Stage 3: Final review of network structure and research activity with subsequent evaluation of the extent and nature of the changes over the duration of the DEMO-net project.

3 Study methodology

All of the FP6 SNA studies reported on in the previous section focused on the organisation or institution as the unit of analysis. Additionally, their data was gathered objectively from publicly available records such as EC records of project participation and co-authorship of papers. In this study we focus on the relations or ties that exist between pairs of individuals (or dyads) (Wasserman and Faust [18]) within the DEMO-net consortium. By collecting data about all of the relations within the network it is possible to examine and reflect on the nature of the network as a whole and the roles and positions of individuals (or nodes) within the network. In some instances we found it useful to collect data that indicates the strength of a relationship eg number of projects worked on together. This is known as valued data as opposed to binary data which simply indicates that a relationship exists between individuals. It can also be useful to know the direction of some types of relationship. For example it is useful to know that x acknowledges y in research papers but y does not acknowledge x. In this study we are have investigated two types of social ties (Wasserman and Faust p.18 [18]). These are ties that can be identified through behavioural interaction eg organising a conference or workshop together; working on a funded research project together; and, formal and informal relationships eg supervision of PhD students.

A roster style web-based questionnaire was constructed in which participants were asked to reflect on their relationships with others prior to start of DEMO-net. Specific questions were devised to

establish the nature and extent of the relations between DEMO-net members and these can be grouped into two as follows:

Group 1: Formal research co-operation:

Q1 Worked on a funded research project

Q2 Worked on a research proposal

Q3 Published research (eg. published a research paper or a research report together; jointly edited a research oriented book)

Q4 Acknowledged or been acknowledged in a research publication

Q5 Organised a conference or workshop

Q6 Undertaken or hosted an academic visit or exchange

Questions in Group 1 were measured in scalar form, allowing valued data to be collected which reflects the strength of the ties being measured, whilst questions in Group 2 only allowed a Yes or No response and thus yielded binary data. For Q7 (PhD supervision) this was a valid decision as there is a high probability that only ONE PhD supervisory relationship would exist between any pair of participants; for Q8 (mentoring) it was felt that it would be harder to recall specific numbers of times when a mentoring relationship took place (rather than for example recalling how many times joint conference organisation had occurred); for Q9 and Q10 where a high level of interaction was anticipated it was felt that it would have been very difficult for an individual to recall exactly how many times they had, for example, sent information about calls for papers or conferences to each of their contacts.

Group 2: Informal links and supporting researchers

Q7 Supervised (eg PhD supervision) or been supervised by

Q8 Mentored (eg. reviewed draft papers or draft project proposals)

Q9 Asked advice or sought information about research

Q10 Sent information (eg. about forthcoming conferences, project 'calls' etc)

Whilst all of the questions except Q9 and Q10 are reciprocal in nature we have, in most cases not made any assumptions about the reciprocal nature of responses. However, for Q4 (acknowledged by another) and Q7 (supervised by another) we have assumed that the response is true even if the person being acknowledged (or supervised) does not indicate this in their own responses to the questionnaire. Although this is a reasonable assumption we accept that there may be errors if the confirmation of an acknowledgement (or supervision) is missing.

The population for the purposes of this study included all researchers who were listed on the DEMO-net website as of March 2006. The initial researcher population was comprised of 78 individuals from 20 organisations, across 11 countries. All 78 researchers were asked to complete the web-based questionnaire. Even though we received 74 responses we could not use all of these. Six responses were made by individuals who were ineligible and whom we had not invited to complete the survey and these were therefore not included. After repeated reminders to complete the survey the remaining 11 (14%) non-completions were zero-filled. The effect is to understate the number of links within the network and to distort the data relating to members of the population with few recorded links. In all, 78 individuals were included in all the datasets used in this study.

4 Analysis and Discussion

The aim of Phase 1 was to map the cohesiveness and structure of the DEMO-net network of researchers at the very start of the project. The analysis focused on examining the overall cohesiveness of the network, the importance of particular players within the network, and the structure of the network as characterised by its structural sub-groups. Analysing the data enabled us to identify stronger and weaker relations within the network and to hypothesise about the reasons for these differences. Once data has been gathered under Phases 2 and 3 we will be able to determine the extent of network growth and examine the nature of any structural change. Analysis was undertaken using Microsoft Excel and the SNA software tools UCINET (Borgatti, Everett and Freeman [4]) and NetDraw (Borgatti [3]).

4.1 Cohesiveness of the network

Examining the cohesiveness of the network, as characterised by the strength of connectivity across the entire network, enabled us to identify those areas of consortium activity which may become useful indicators of network growth in future analysis. From the network data obtained from the answers to each question we calculated both the density and geodesic distance. Both of these are indicators as to how quickly knowledge might spread throughout the network. Given that the datasets derived from each question are from the same population (n=78) it is valid to undertake cross-question comparison of the densities and geodesic distances. For comparative purposes the

data from all datasets were converted to binary mode and the corresponding density and geodesic distance values are shown in Tables 1 and 2.

Table 1. Density of networks generated by each question

Density	Q1	Q2	Q3	Q4	Q5	Q6
Binary	.0283	**.0345**	.0171	.0186	.0183	.0067
StdDev	.1658	**.1824**	.1298	.1353	.1341	.0813

Density	Q7	Q8	Q9	Q10
Binary	.0063	.0216	**.0420**	**.0631**
Std Dev	.0793	.1455	**.2005**	**.2431**

Inspection of the density results demonstrates the need for careful construction of SNA questionnaires and caution in interpretation of results. Perhaps unsurprisingly, the Q9 (seeking information) and Q10 (Sent information eg. about forthcoming conferences, project calls etc) networks have the highest overall network densities. More significantly perhaps is that the next highest density, with a lower standard deviation falls to Q2 (worked on a research proposal together). However, even this result has to be treated with caution as a participant may have included 'working on DEMO-net' as one of their relations even though they were asked to report only about their relationships prior to DEMO-net.

Table 2. Geodesic distance for each question

	Q1	Q2	Q3	Q4	Q5	Q6
Average Distance	3.219	2.826	4.285	3.519	3.800	**2.167**
Distance based cohesion	0.097	**0.159**	0.062	0.055	0.065	0.012

	Q7	Q8	Q9	Q10
Average Distance	**1.443**	3.295	2.936	2.554
Distance based cohesion	0.008	0.074	**0.185**	**0.251**

To investigate the cohesiveness of the network further we also looked at the geodesic distances. In any given network the average geodesic distance represents the average shortest path between reachable pairs of nodes (Borgatti et al [4]). The distance-based cohesion results lies in the range 0 to 1 with larger values indicating greater cohesiveness.

The lowest average geodesic distance can be seen in the network for Q6 (Academic visits and exchanges) and Q7 (Academic supervision). However in both these networks there are significant numbers of individuals without connections to any others (isolates) because, prior to the start of DEMO-net, there were not many exchanges or visits and a relatively low number of PhD supervisions. This means that very few pairs of nodes have been used to calculate the average distance and thus the geodesic distance for these datasets should be ignored. The three networks with the next lowest average geodesic distances are those representing Q10 (about sending information; 4 isolates) Q9 (about seeking information; 9 isolates) and Q2 (about working on research proposals; 13 isolates). Given the nature of the questions, the density of these networks (see previous section) and the relatively low number of isolates these would seem to be more reliable average geodesic distance results.

This analysis of the relative cohesiveness of the networks through average geodesic distance can also be confirmed by looking at distance based cohesion. Q10, Q9 and Q2 have the largest values – where the higher the value the greater the cohesiveness of the network. Q7 and Q6 have the lowest distance based cohesion values indicating that although the average geodesic distance between reachable nodes is low there is, in the network as a whole, a lack of cohesiveness. These differences in cohesion can also be seen in the network diagrams shown in Figs 4 and 5.

In the above discussion we have identified interesting variations in the cohesiveness of specific networks. In the conclusions, we consider what these variations mean in relation to the state of the NoE at startup.

By reviewing the datasets with the most cohesive networks first, it becomes possible to identify which are likely to be most rewarding to review in most detail at this point.

4.2 Centrality: Identifying key players

It is common, in research networks, to find influential researchers who have central, pivotal roles. Some of these may be readily identifiable by those working both inside and outside of the research network. For example, in an NoE we would expect the Work Package Leaders to be both influential and well respected by their peers. The status of the Task Leaders is less certain and we will return to this issue periodically in this discussion. Using the SNA centrality measures of indegree and outdegree may also help to identify young or emergent researchers whose influence might grow over the duration of the project. Outdegree tells us about the role of each person in the network. It shows how many relations each person has in an outward direction (Borgatti et al [4]). For each question we were able to establish the person's self-

perception of how active they are in the network. In questions where we asked participants about the frequency of the connections they have with others the outdegree shows the total number of relations – not the total number of people to whom an individual is connected through outward connections. For indegree, we were able to establish how influential each person is, as seen by the other network members, in relation to the particular question answered. Indegree can be argued to be the more objective measure as it derived from the responses of others.

We looked at responses to Group 1 questions, relating to research co-operation. As a basic approach to the data, the number of in-going and out-going relations were used to categorise and rank individual network members. The focus is on ranks, rather than directly comparing the (relative) number of relations as this provides a simple mechanism for cross-question comparison. The individuals appearing in the top half of the ranked positions were compared with the Task Leaders in DEMO-net in an attempt to measure the extent to which the organisational structure of the DEMO-net project correlated with the perceived importance of individuals as evidenced by their ingoing and outgoing relations.

Initially, we thought that people with the most incoming relations from colleagues could be assumed to be the authority figures within the network. However, after careful consideration we decided that they could only be considered to be 'key players' if they also had a high number of outgoing relations ie they were demonstrating that they were also important contributors to the network's cohesiveness. If they have a high level of ingoing relations and a low number of outgoing relations, they can be seen as authority figures supporting the network but they do not contribute significantly to extending the knowledge-base of the network as a whole. It should be noted however that it may be that their outgoing relations are to people outwith the current membership of DEMO-net.

Table 3. NoE players

		Outdegree rankings	
		High	**Low**
Indegree rankings	**High**	A. Key player	B. Authority figure
	Low	C. New to field	D. Unmotivated member or junior researcher

Researchers whose main field is outside eParticipation, or who are new to the field, would be expected to have a high number of outgoing relations, because they are constantly seeking new knowledge from others, and a relatively low level of incoming relations because their views and opinions are not yet highly valued (Table 3). Researchers with low/low ranking positions may be passive, unmotivated members or they may be junior researchers who are learning the skills of working in a research network.

4.2.1 Analysis of individual questions: Q1, Q2 and Q10

Selecting the questions with the greatest density ie Q1 (Participated in a funded research project), Q2 (Submitted a Research Proposal) and Q10 (Sent information) we compared the indegrees and outdegrees. As an aid to understanding the figures, we plotted graphs to compare the frequencies of different levels of in- and out- degrees for each question; trend lines have been added to aid understanding. An example is shown in Figure 1.

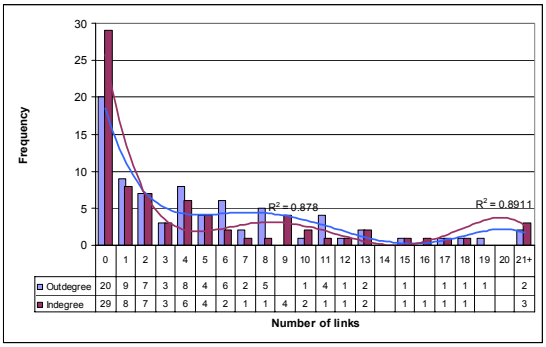

Figure 1. Comparative indegree/outdegree frequencies: Q2 (Research proposals)

As might be expected, indegree scores are higher and more focussed on a smaller number of people than outdegree scores. There are more people with no inward links at all, with a few individuals having a very large number of inward relations with others. Most people have at least some outward relations with others, with comparatively few having none (ie the outdegree trend line is higher than the indegree in the middle of the range).

Comparing the top 10 outdegree and indegree scores between the questions, we found the same 8 people are ranked in the top 10 for outdegree for Q1 (project participation) and Q2 (proposal writing). At four, the overlap of the people with the highest number of indegrees is lower, perhaps reflecting the greater need for active outward networking when writing and cooperating on projects.

4.3 Network Structure

4.3.1 Partitioning the network

There are several approaches available for finding sub-groups within a network. One is to look at who is relating to whom, which we consider in section 5.3.2. Another is to look at how the network can be divided into groups; the most effective depends on the shape of the network. We looked at two network analysis methods: **factions**[1] and **core/periphery.** The core/periphery structure is one that would be expected in an established coherent community in which there are a group of densely connected people in the core of the community who are able to coordinate and control their actions. Those in the periphery are less densely connected to each other and to the members of the core (Hanneman and Riddle [8]). As Hanneman and Riddle note "actors in the core are at a structural advantage in exchange relations with actors in the periphery". In contrast, factions describe "…a society in which each person was closely tied to all others in their own sub-population (that is, all sub-populations are cliques), and there are no connections at all among sub-populations." Both these approaches *partition* the network – that is, all members are assigned to one or another group, even if the fit is not that good. It is therefore essential not to over-interpret the data.

In an attempt to better understand the nature of sub-groups within collaborative project work we merged the responses to Q1 and Q2, thus combining the data relating to working on research proposals with the data on working together on projects. Using factional analysis with a range of factional group sizes (2, 4, 8 and 12) we found that when the number of factions is high, the factions correspond closely to institutional allegiances. Reducing the faction-count to 4, the population coalesces around two major groups. Faction 1 contains 34 people grouped around UK, Greek and German institutions, Faction 2, 20 people mainly in Scandinavian/Nordic institutions. However, the error rate was high because there are many cross-links between researchers in all the participating DEMO-net institutions. Figure 2 shows how the same network can be partitioned between 4 factions and a core/periphery model. The dotted ellipse corresponds roughly with the core of the network. The colours represent a possible partition of the network into four groups (factions). Note that most people are in Group 1 or 2, however the number of cross-links between these groups shows that the factional breakdown of the network is weak.

[1] This refers to factions as defined later in the SNA context rather than contentious minority groups

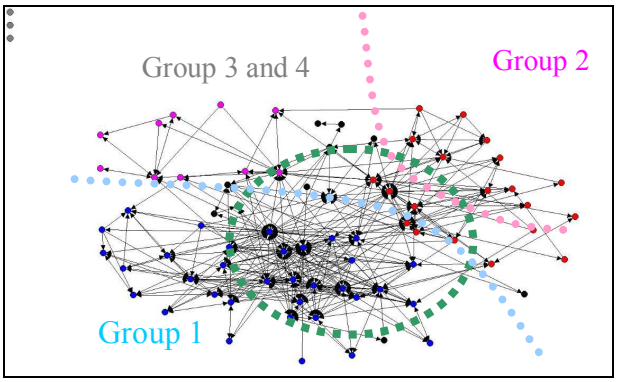

Figure 2. Partitioning the population

4.3.2 N-cliques

In contrast to the partitioning approach taken above, n-cliques are discovered by measuring the length of the paths between individuals, with n being the maximum path length at which clique members are connected (Scott [15]).

In the combined Q1 and Q2 responses, 78 2-cliques were found, and 25 3-cliques, although it has to be remembered that n-cliques overlap with each other. Being in a 3-clique means being connected to everyone directly or up to and including a friend of a friend of a friend – which seems a bit remote in terms of networking for research purposes. 23 people are members of 20 or more 3-cliques, 15 of them are also part of the Core, the other six include non-academic members (such as practitioners or managers) and senior figures who may have chosen not to fully participate in this network. Eight people are not even members of one 3-clique; although none of these are part of the Core, two are Phase 2 Task Leaders (reflecting the importance of their role in the network). If this result is repeated in the Stage 2 survey, the consortium should give consideration as to how to engage and support those members that are shown to be remaining isolated.

In comparison, 2-cliques (a tighter grouping than 3-cliques) are equivalent to being connected to everyone in the group directly or through a friend of a friend. Twenty-one people appear in ten or more 2-cliques. We matched these against the 21 Phase 2 Task leaders. Table 3 shows that 14 Task Leaders are in 10 or more 2-cliques. Seven however are not and this reflects the nature of DEMO-net consortium where two Task Leaders are practitioners working in government (and previously not linked to the academic community). The absence of the others from significant membership of 2-cliques may reflect their movement within the academic field in the year since the project started. From the 2-clique data we can tentatively identify two factors in relation to the allocation of responsibility

within the project in Phase 2. Firstly position within the network at the start of the project is significant. Secondly, new people are being brought into the network and these should show greater integration (perhaps in the Core) in subsequent surveys.

Table 3. Analysis of Phase 2 Task Leaders

	Core	Non-core	Group 1	Group 2	Total
In 10 or more 2-cliques	10	4	10	4	14
In < 10 2-cliques	1	6	3	4	7
Total	11	10	13	8	21

4.4 Consolidating centrality and structure

Bringing together the analysis of indegree/outdegree and network structures we focus on those DEMO-net members who are in the top half of the indegree and outdegree rankings. Those researchers achieving low/low rankings are not investigated further here. Table 4 shows the number of individuals who appear in the top 5 in- and outdegree rankings for all questions, their status as WPL/TL and their positions within the network Core and each of the main groups or factions.

Table 4. Role, centrality and structural position

	No.	WPL	TL	Core	Group 1	Group 2
A:(High High)	9	4	5	8	7	2
B:(Low High)	6	1	1	4	5	1
C:(High Low)	6	0	1	3	5	1

A: in top 5 indegree and outdegree for all questions
B: in top 5 indegree but not in top 10 outdegree for any question.
C: in top 5 outdegree but not in top 10 indegree for any question.

There are 12 WPLs in DEMO-net phase 2 TLs and we might expect that that there would be more than one third of these appearing within the high/high in/outdegree category (n=4/12). However, one of those people not in the high/high category is mainly responsible for project management and would not therefore be expected to contribute significantly to the type of research activities that was the focus of our question. Two others work in e-government outside of the academic sphere so the nature of their work is probably less focused on the type of academic relationships that we were enquiring about. The other 4 are academics, 3 of whom appear in 13, 17 and 20 2-cliques respectively – thus demonstrating a relatively high level of connectivity outwith the Core and faction level; whilst the other only appears in 1 2-clique and is thus somewhat less connected to others than we might expect for a WPL. Although it appears that the amount of activity between WPLs and others in the network is not evenly spread between them, when we look at the structural organisation of the network we find that all WPLs are part of the Core and all but one are in factional Group 1.

The 21 Task Leaders are even less well represented in the high/high in/outdegree category (n=5/21). However, this can be readily explained as project Tasks can be quite focused, with the bulk of the work being done within one organisation or institution. Additionally, the role may also be occupied by a more junior researcher.

4.5 Data from other questions

The work in the previous sections focussed on the dense networks produced by questions 1, 2 and 10. Responses to some of the other questions did however produce some interesting network structures which we now briefly explore. Several of the networks have low density and a number of cut-points (Figures 3 and 4). The large number of cut-points is probably an indication of the immaturity of the network at the time of the survey and in the case of Q3 (Figure 3) the personal nature of co-publishing. We would expect that as DEMO-net matures the networks will become richer, more extensive and more dense, and the number of cutpoints will reduce. In particular, we would expect the density of the Q6 (Visit/exchange) network to have increased over 2006/7 if the DEMO-net project has been at all successful. On the other hand, we would not expect the isolated structure revealed by Q7 relating to PhD supervision (Figure 5) to change significantly. The nature of the relationship will remain one-to-one, and largely intra-institutional. It can be expected that the significance of some of the social networks will change as DEMO-net evolves.

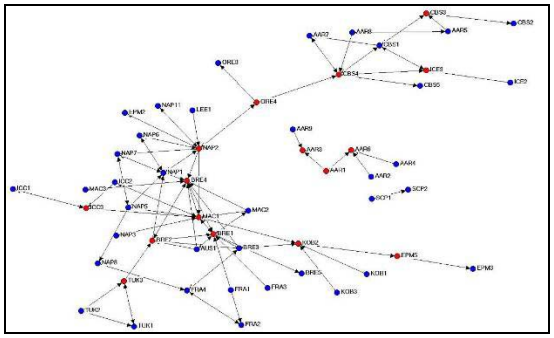

Figure 3 Q3: Published research

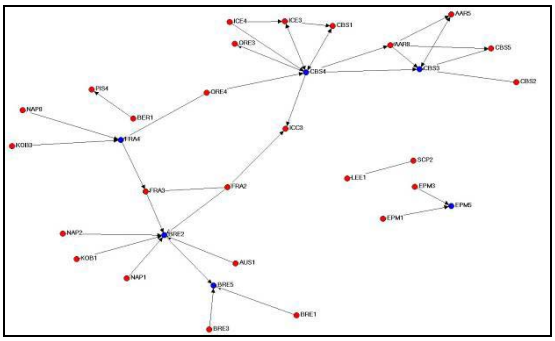

Figure 4 Q6: Undertaken or hosted an academic visit or exchange

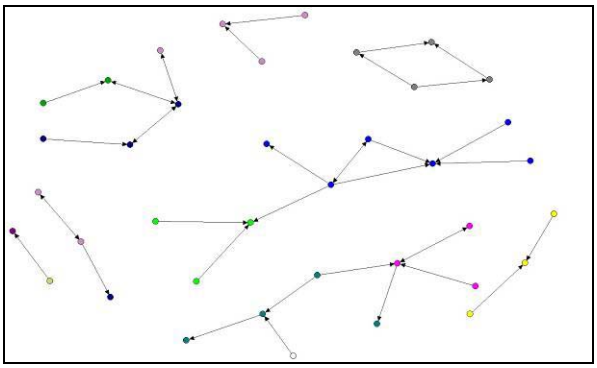

Figure 5 Q7: Supervised

5 Conclusions

SNA has enabled us to review and reflect on the nature of DEMO-net. Examining the density of the different types of networks (formalised academic associations, informal information exchange and support or mentoring networks) provides some insights into the way in which a newly established research network operates. The higher densities found in the informal networks used for sending and receiving information suggest an initial desire to make contact with new people, to share knowledge and to foster relationships. It is possible, that over time these networks which rely on one-to-one or one-to-many information exchanges may decline in density as DEMO-net introduces more organised methods of information exchange (eg web portals, discussion lists). In the initial stages of this research network we are observing a high density in the network involving working on a research proposal (Q2). Writing research proposals can be considered to be the initial input stage in the research cycle. Over time, as research proposals turn into funded projects, we might expect to see the density of Q1 (worked on funded research project increase). With the passage of even more time we might also expect that networks concerned with research output (eg Q3: published research; Q4: acknowledgements) will become more dense as research is completed and joint papers reach the publication stage. However, if, as Breschi and Cusmano [5] suggest, DEMO-net develops an oligarchic core then such connectivity is less likely to occur and we will instead see greater research output (as evidenced through project collaboration and publications) and connectivity (indegree/outdegree in areas such as seeking/providing information) developing amongst core players with little strengthening of such activity at the periphery.

The key finding in respect to the usefulness of SNA as technique to evaluate the nature of the DEMO-net research network is that the SNA Stage 1 results accurately reflect the reality of the operation of DEMO-net. We have demonstrated this by comparing the Stage 1 SNA findings with allocations of responsibility (WPL/TL) within Phase 2 of the project. We used DEMO-net Task leadership to show that centrality is correlated to the role of network members in the project. Examining in/out degree, however, has been shown to be insufficient on its own. Additional and more significant insight can be drawn from examining 2-cliques. This is because getting a task leadership role is not only dependent on your own relationships with others, it is also affected by the relationships that your collaborative researchers have with others (ie it matters who are friend's of your friends). This emphasises the usefulness of specialist social network analysis tools such as UCINET in comparison to Excel, which is only useful for examining direct links.

There are a number of limitations to the study. When the Stage 1 SNA survey was conducted zero-responses were used to compensate for missing data from 11 (14%) participants. This will have skewed some of the results. Additionally, there was some inaccuracy in responses because participants were being asked to reflect on relations existing prior to start of DEMO-net. We know, for example that some individuals included 'working on DEMO-net' as one of the projects on which they were collaborating, even though they were asked not to include this project.

The SNA results presented here have also been reported within the DEMO-net research network itself. Reports to the DEMO-net community have largely been presented at a high level, reporting on the shape and structure of the network, rather than focusing on specific participants. It is likely, however, that the results of the social network analysis will impact on structural changes occurring within DEMO-net in the future. This should not be seen as a negative influence but rather it could be developed further using an action research approach.

Additional work needs to be done to look at the data at an institutional level: which institutions are good at external networking? Are there differences between how individuals and institutions interrelate both internally and externally? It may be worth

considering people ranking low for degree centrality and looking at their relations with the key players. There are a number of possible hypotheses that could be tested, for instance:

- As the network becomes more coherent, the number of people with high indegree will fall (that is, fewer people will take 50% of the indegree relations)
- The number of outward relations will rise as people get to know each other
- The size of the network will increase
- The number of cut-points will decrease

Additionally, If DEMO-net is at all successful, it would be expected that the number of relations in the Q6 (Academic visits and exchanges) network would increase over the duration of the project, while the nature of the Q7 network (PhD supervision) would be expected to remain more or less constant.

The method used for the re-survey must allow for new members to have joined the network, and some members to have dropped out. Now that DEMO-net has matured and as it enters Phase 2, identifying targets for the survey should be more straightforward, though there will always be the risk of omitting network members. This risk can be partially mitigated by ensuring that all the people known to be working on Tasks and Work Packages are included. This will provide a check that will ensure that the central members of the network are included in the second stage survey. The follow-up survey can also be configured to only accept responses from a pre-defined population, ensuring that only the members of the network that we have identified can complete the survey.

Combining and clarifying questions will be part of the strategy for improving the integrity of the network data. Given that the network will have grown, the number of questions might be reduced to keep the survey as simple and as quick as possible to complete. Further consideration will also be given as to which directional and valued relationship-data is actually required (eg working on a research proposal is bi-directional, whereas acknowledging an authority is directional). A combination of all these measures should ensure a high level of participation in the Stage 2 follow-up survey.

6 References

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