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Social Networks in which Users are not Small Circles

Sabah Al-Fedaghi and Heba AlMeshari
Computer Engineering Department, Kuwait University, Kuwait

sabah.alfedaghi@ku.edu.kw **h_almeshari@yahoo.com**

Abstract

Understanding of social network structure and user behavior has important implications for site design, applications (e.g., ad placement policies), accurate modeling for social studies, and design of next-generation infrastructure and content distribution systems. Currently, characterizations of social networks have been dominated by topological studies in which graph representations are analyzed in terms of connectivity using techniques such as degree distribution, diameter, average degree, clustering coefficient, average path length, and cycles. The problem is that these parameters are not completely satisfactory in the sense that they cannot account for individual events and have only limited use, since one can produce a set of synthetic graphs that have the exact same metrics or statistics but exhibit fundamentally different connectivity structures. In such an approach, a node drawn as a small circle represents an individual. A small circle reflects a black box model in which the interior of the node is blocked from view. This paper focuses on the node level by considering the structural interiority of a node to provide a more fine-grained understanding of social networks. Node interiors are modeled by use of six generic stages: creation, release, transfer, arrival, acceptance, and processing of the artifacts that flow among and within nodes. The resulting description portrays nodes as comprising mostly creators (e.g., of data), receivers/senders (e.g., bus boys), and processors (re-formatters). Two sample online social networks are analyzed according to these features of nodes. This examination points to the viability of the representational method for characterization of social networks.

Keywords: Social network, network structure, user behaviors, node interior, conceptual representation

Introduction

According to Cohen (2009), “the essence of the Informing Science philosophy is the *transfer* of knowledge from one field to another: breaking down disciplinary boundaries that hinder the flow of knowledge” [italics added]. Naturally, this transfer requires a “delivery system” (Cohen, 2009), and this is established on the mechanism of networking. Here, networking refers to the communal linkages between members as the principle of connection between them regardless whether these constituents are computers, humans, or robots. The members of a network are deliberately linked with each other and have roles to play in achieving the purposely constructed goals of the network. Networks form patterns of contact in the

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broadest sense, and these contacts can move from one point in a network to another or can be co-created by network members (Monge & Contractor, 2003). It can be argued that each discipline (Cohen, 2009) is based on a network that facilitates the transfer of knowledge in that discipline. Accordingly, networking in these networks is the role of informing science.

> Informing Science is the union of aspects of these disciplines, the aspects that relate to informing clients. Its purpose is to inform these disciplines. By union, I mean more than just summing all the work. There is synergy in bringing together researchers from diverse fields to bear on the common problem of how best to inform clients. (Cohen, 2009)

Specifically, this paper deals with social networks as "informing networks" (Rambe & Ng'ambi, 2011) that intercross the disciplines of networking (online social networks, OSNs), computing, behavioral and social sciences, diagrammatic modeling, and graph theory.

Understanding of social network structure has important implications for many aspects of computer science and software engineering. First, studies of user behaviors allow the performance of existing systems to be evaluated and lead to better site design (Burke, Marlow, & Lento, 2009; Wilson, Boe, Sala, Puttaswamy, & Zhao, 2009) and to applications such as ad placement policies (Williamson, 2007). Second, accurate models of user behavior in OSNs are crucial in social studies as well as in online areas such as marketing. For instance, marketers might want to exploit models of user interactions to spread their content or promotions quickly and widely (Leskovec, Adamic, & Huberman, 2007; Watts & Peretti, 2007). Third, understanding how the workload of social networks is reshaping the Internet is valuable when designing next-generation infrastructure and content distribution systems (Krishnamurthy, 2009; Rodriguez, 2009). In this context, recent studies have examined these patterns by using data gathered from online social sites, for instance, writing messages to other users (Chun, 2008; Huberman, Romero, & Wu, 2009; Viswanath, Mislove, Cha, & Gummadi, 2009; Wilson et al., 2009), or by accessing third party applications (Gjoka, Sirivianos, Markopoulou, & Yang, 2008; Nazir, Raza, & Chuah, 2008; Viswanath et al., 2009).

The characterization of social networks has been dominated by study of topological characteristics (e.g., Ahn, Han, Kwak, Moon, & Jeong, 2007). Graph representations are analyzed in terms of *connectivity* using techniques such as degree distribution, diameter, average degree, clustering coefficient, average path length, and the degree of loops or cycles. According to Gong et al. (2012), traditional social network studies are based mostly on the topology of the network, i.e., a user is a node, and a relationship (e.g., friendship) is represented by a link. Statistics are used to describe general trends; however, in social networks, statistics are not completely satisfactory in the sense that they cannot account for *individual* events. Graph metrics that characterize the connectivity structure have only limited use since "one can produce a set of synthetic graphs which have the exact same metrics or statistics but exhibit fundamentally different connectivity structures" (Oregon Network Research Group [ONRG], 2014). Roth (2005) argues against the credibility of some graph features in characterizing social networks, as follows:

1. *Node degree* seems to be inaccurate for some types of real networks (Barabási et al., 2002), and possibly based on flawed behavioral foundations
2. Strict *topology* and derived properties may not be sufficient to account for complex social phenomena
3. Single parameters cannot express the rich heterogeneity of interaction behavior
4. Often models assume properties to be uncorrelated when it is not the case

In the absence of a more careful and meaningful characterization of graph connectivity, it is difficult to examine the structural properties of these systems, study their evolution over time, or compare the connectivity graphs of different systems. (ONRG, 2014)

Recently, there has been interest in describing user attributes in characterizations of social networks, which could be static (e.g., school, city), or dynamic (e.g., online interest). Roth (2005) distinguishes between single node properties, and node, e.g., social distance. According to Gong et al. (2012),

> Most prior work in the measurement and modeling space focuses primarily on the social structure […]. Measuring social-attribute networks can simultaneously inform us of the properties of social networks […]. Several recent results suggest that augmenting the social network structure with *user attributes* […] can provide a more fine-grained understanding of social networks. (italics added)

Note that attributes can also be applied to edges in a graph, e.g., a business or a romantic relationship. Also, recently, there has been great interest in measurement of observable activities such as distinguishing active relationships from weak relationships (Chun et al., 2008). For example, studies have revealed that passive interactions such as profile browsing often dominate user events in a social network (Benevenuto, Rodrigues, Cha, & Almeida, 2009; Jiang et al., 2010). In general, properties are analyzed at the level of individual, links, or incidences.

This paper suggests a local node level analysis through consideration of the *structural interiority* of a node, providing a more fine-grained understanding of social networks that can help in augmenting social network structure and user attributes.

Graphs are utilized generally to represent diverse things and their relationships. In general networks, a node is a single processing unit; i.e., it takes input, processes it, and makes it available from its output port (Silipo, n.d.). In social networks, an individual is represented by a node drawn as a *small circle*. A small circle reflects a black box model in which the interior of the node is blocked from view. Such a conceptualization dominates almost all studies of social networks. For example, in studying disruption of illegal networks, it is declared that "Each criminal is represented by *a small circle*, and the lines connecting criminals represent the collaborations between criminals" (McBride & Caldara, 2013). In chat room visualization, "each participant is *a colored circle*" (Yang, 2005). In analyzing teacher communities "each *small circle* represents a member of the faculty, and ... Resource teachers and leaders are represented by gray dots" (Penuel, Riel, Krause, & Frank, 2009).

This paper proposes a structural characterization of the interior of social network nodes through modeling of the inner space into six generic stages: creation, release, transfer, arrival, acceptance, and processing of the artifacts that flow among and within nodes. This characterization is different from use of so-called "*actors' characteristics* – indicators of performance and success, attitudes and other cognitions, behavioral tendencies" (Snijders, Steglichy, & Schweinbergeryy, 2007). The resulting description produces nodes such as mostly creators, e.g., of data, receivers/senders (bus boys), and processors (re-formatters). In this paper, we analyze two online social networks in terms of these features of nodes.

In the next section we give a general description of the flowthing model (FM) that has been used in several applications (e.g., Al-Fedaghi, 2014; Al-Fedaghi & AlMeshari, 2014).

Systems of Things that Flow

Artifacts *flow* in a network, e.g., emails, information; *flow* also occurs within nodes in a pipeline with movement such as reaching a boundary (e.g., port), actual arrival in the node (e.g., input buffer), acceptance as a legitimate input, movement to be processed in the node, movement to a queue to be released, and passage to an output port. The notion of *flow* was first propounded by Heraclitus, a pre-Socratic Greek philosopher who declared that "everything flows." Plato explained this as, "Everything changes and nothing remains still," where instead of "flow" he used the word "change" (Stanford Encyclopedia of Philosophy, 2013). Heraclitus of Ephesus (535–475 BCE) was a native of Ephesus, Ionia (near modern Kuşadası, Turkey). He compared existing things to the flow of a river, including the observation that you cannot step twice into the same river. Flow can also be viewed along the lines of "process philosophy," "championed most explicitly by Alfred N. Whitehead in his 'philosophy of organism,' worked out during the early decades of the 20th century" (Stanford Encyclopedia of Philosophy, 2013).

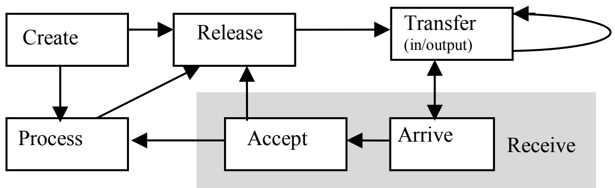

Figure 1: Flowsystem.

Consider an airport as a node in a network of airports. Visualizing the internal travel flow (see Figure 1):

1. *Transfer* as input: A passenger reaches the entrance, where he/she may be refused entry at the security checkpoint.
2. *Arrival*: The passenger arrives inside the terminal at the check-in desk, where he/she may be rejected as a passenger because something is wrong with his/her travel ticket.
3. *Accepted*: The passenger is accepted as a passenger
4. *Processed*: The passenger's passport is processed.
5. *Released*: The passenger is released to the boarding area.
6. *Transfer* as output: The passenger leaves the airport in the aircraft.

A clearer example can be visualized in terms of a network packet flowing in a device such as a modem:

1. *Transfer* as input: The packet arrives at the input port of the modem, but it may be lost due to loss of connection.
2. *Arrival*: The packet reaches the input buffer, but it may be rejected because of parity error.
3. *Accepted*: The packet is accepted as legitimate data.
4. *Processed*: The packet as data is processed, e.g., a stop bit is added.
5. *Released*: The packet is put in an out-buffer queue.
6. *Transfer* as output: The packet flows to the output port.

Additionally, these "things that flow" may be *created* inside the node, e.g., a passenger giving birth to a baby in the airport – or generation of a new packet. Note that sometimes these "flowing things" may also be forced to "back-flow," such as a passenger cleared and waiting to board who is apprehended by the police before getting on the plane. Sometimes, these stages are tied together, such as a release being followed immediately by transfer. Transfer is a no-return stage, as in the case of a packet reaching a port. In the airport travel example, the assumption is that these stages represent the map of a "journey," just as a city map represents all possible flows of traffic. In FM, the environment of flow is called its *sphere*, e.g., a node in the social network, or a *subsphere* in that node, e.g., information, requests, responses. In an object-oriented approach, a class is a sphere and an object is a flowthing.

With respect to a sphere, a flowthing is a thing that has been *created*, or a thing that has come in from outside the sphere. Accordingly, all existing things in the sphere of the Earth are flowthings. Coming into existence from nonexistence is also a kind of flow.

The arrows in Figure 1 denote conceptual flows. A conceptual flow may not be a physical flow. When an automobile reaches a certain physical place in an assembly line, it simultaneously triggers (invokes) two conceptual flows of, say, two robots that fix the doors and the tires, as shown in Figure 2.

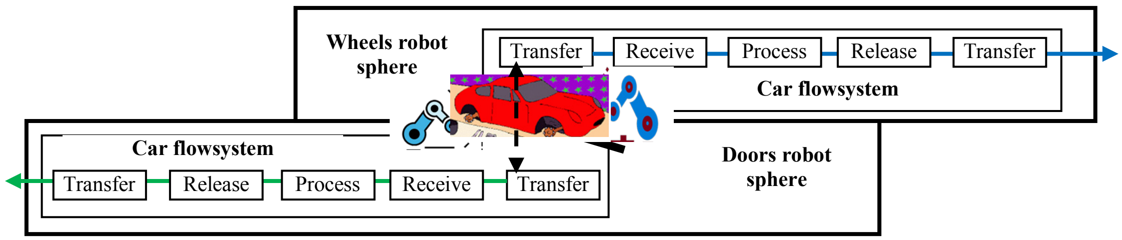

Figure 2: When a car reaches a certain position, it triggers two conceptual flows.

The stages of a flowsystem are mutually exclusive and complete; that is, a flowthing always exists in only one of these states or stages. *Process* in this model is any operation on a flowthing that does not produce a new flowthing. *Creation* denotes the appearance of a new flowthing in the flowsystem (e.g., *if a person is >60 AND diabetic*, then *He is at risk*, where *He is at risk* is new information that has not come from outside but is created internally). Other states of flowthings are not generic, e.g., stored or saved flowthings are in secondary states; thus, we can have created saved flowthings, processed stored flowthings, and so forth.

In addition to flows denoted as arrows, FM includes triggering mechanisms represented by dashed arrows. Triggering denotes activation, such as starting a new flow, and this will be illustrated in the following example.

Example of FM representation: Tillers (2007) used scenarios to describe events in the field of legal investigation and proof. "An investigator's purpose in forming scenarios is akin to, but not the same as, a fiction writer's objective in doing so. An investigator's scenario contains fictive or hypothetical events, but an investigator's purpose in making conjectures about events and in forming scenarios is, at least sometimes, to figure out what actually happened." Figure 3 shows Tiller's (2007) sample diagram of such a scenario. The solid black circles "represent evidentially well-established benchmark events and the empty circles, entirely hypothetical events." To simplify the diagram, his color difference in circles will be ignored when constructing the FM representation of the scenario shown in Figure 3.

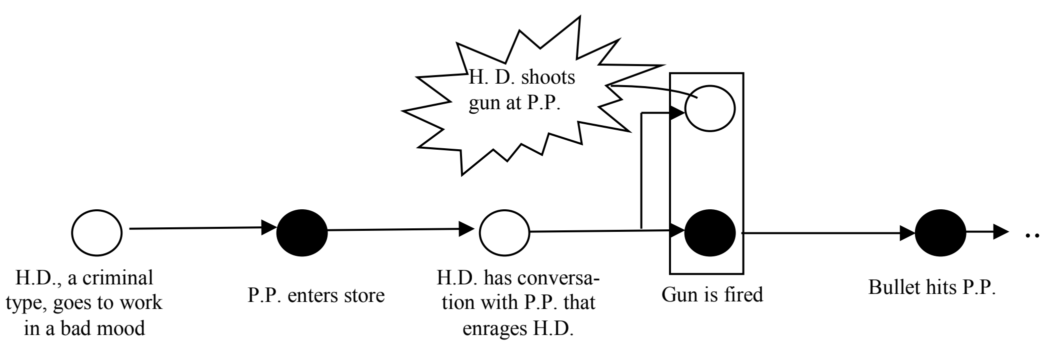

Figure 3: A sample scenario (partial from Tillers (2007) with minor modifications).

Figure 4 shows the FM representation that corresponds to the investigator's scenario. It involves two special spheres: a Store (circle 1) and Outside the store (2). In the outside sphere, there is the sphere of H.H. (3) who is described by his Work (4), Character (5), Mood (6), and his physical self/body (7). *Create* in these flowsystems refers to constructor-ing (to use object-oriented terminology) this character, H.H., in the scenario for the first time. This is analogous to the "popping into existence" of an actor on the stage for the first time, e.g., a person enters wearing a sailor's uniform (generating the impression that he is a sailor), walking with a drunken swagger and flailing gestures (generating the impression that he is drunk). *Create*, here, is communicating information about a scene; however, the physical self goes beyond mere appearance by moving (flowing) from the outside into the store (8). H.H. is received in the store, entering (9) and getting involved (10) in a Conversation (11).

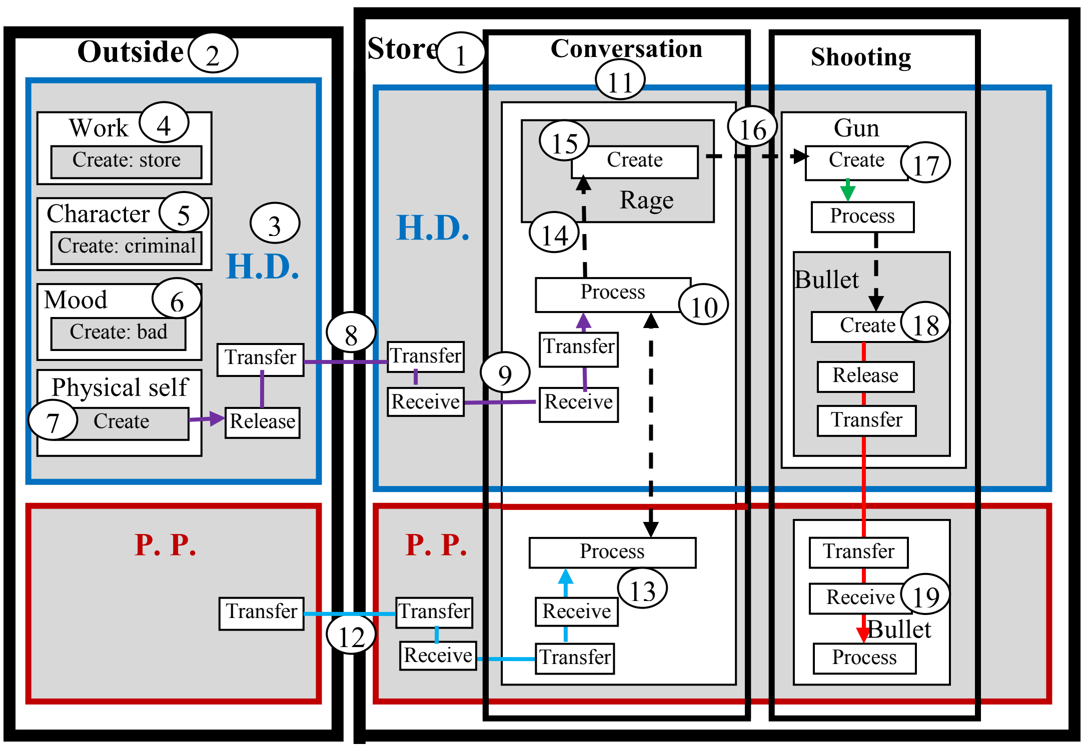

Figure 4: FM representation of the sample scenario.

The other party in the conversation, P.P., comes from outside into the store (12) and engages in the conversation (13). The conversation triggers (14) a reaction of rage (15) in H.H., which in turn triggers him (16) to pull out (create – 17) a gun. This triggers a shooting (18) that hits P.P. (19).

Applying FM in Social Networks

This section discusses some of the notions that are introduced in graph-based representations of social networks. As mentioned previously, recent interest in measurements of user observable activities has been great (e.g., Benevenuto et al., 2009; Chun et al., 2008; Jiang et al., 2010).

Measuring Importance

Example: Bin (2014) considered the social network formed by 5 nodes shown in Figure 5 and conducted "quantitative analysis that includes such measurements as the following: Cutpoint, Bridge, degree of a node, Geodesic path, Geodesic distance calculated in terms of a table that includes Density, N-Clique, Centrality, Degree centrality, Closeness centrality, and Betweenness centrality." Accordingly, Bin (2014) gives some observations:

> It is easy to know that David is the most influential node. From degree centrality, we can see that the indicators of David are the largest. And from closeness centrality or betweenness centrality we can make the same judgment.

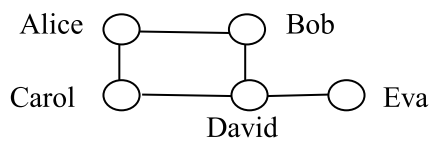

Figure 5: Social network.

But such results give just one interpretation of many that can correspond to the graph of the given network. For example, if we incorporate the internal processes occurring in the nodes, it is possible to describe the network in terms of FM, as shown in Figure 6.

Assume that a close inspection of the network reveals that Alice generates (circle 1 in the figure) project proposals that flow to David (2), who acts as the "bus boy" for the group. He sends the projects to Eva, Bob, and Carol (3, 4, and 5, respectively). Eva takes the role of a librarian who keeps copies of the projects (6).

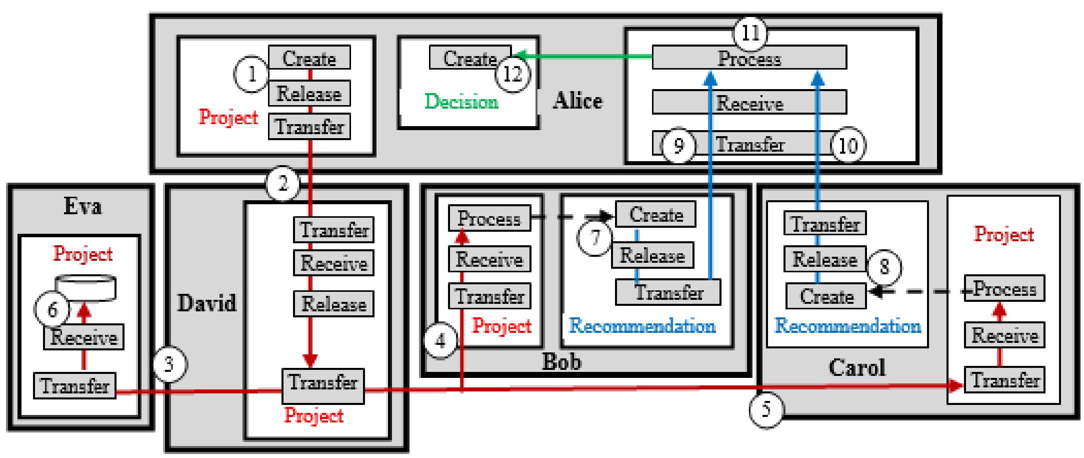

Figure 6: FM representation of the network

Bob and Carol are assistants who make recommendations about projects (7 and 8, respectively) and send their recommendations to Alice (9 and 10, respectively). Upon receiving the recommendations, Alice processes them (11) and makes decisions (12). To make all nodes bidirectional, we assume that each person sends an acknowledgment upon receiving a flowthing. (Acknowledgment flowsystems are not shown in the figure.)

Analysis of the FM representation produces completely different values for the nodes of the network. The generator and decision maker in the network is Alice. She can probably manage the process even if the others are cut off.

Example: Pomffyova (2010) uses "a social network diagram as a map of all of the relevant ties between the nodes which are being studied." The interest in that study is small companies in which employees in top positions are family members. A case study is presented with the objective of determining "the social capital of individual actors." The small enterprise in its social network diagram is shown in Figure 7, where people are displayed as nodes Yi and their social relationships are links. Y1 is a chief executive, Y2 is his wife, Y3 is a sales and marketing manager, Y4 is an accountant, and the other two are regular enterprise members.

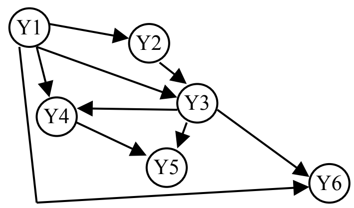

Figure 7: Social network diagram (from Pomffyova, 2010).

According to Pomffyova (2010), "next in that social network we must know the most significant nodes and their properties–centralities… a person who controls information flows is more important than one who is on the topic position… There, it is a node Y3. If such a worker absents, information flows from Y2 to Y4, Y5 and Y6 absent."

As discussed in the previous example given by Bin (2014) – a network comprising Alice, Bob, Carol, David, and Eva – the type of internal role of the node can shift a decision about the importance of any node. Pomffyova (2010) settled this issue in her network by describing the role of Y1 as a "chief" who's preparing "plans for firm's stock-in-trade as well as enterprise strategy," while Y3 always has "better information about sales promotion so he can better plan purchase orders." It is possible to make Y3 just an assistant to Y1, who also does sales as in, say, a small real estate company. In this case, obviously, Y1 is more important than Y3 even in Y3's absence.

Importance and Type of Flow

The example given by Pomffyova (2010) provides the opportunity to exhibit and explore additional features of the FM representation of a social network. The FM description is based on identifying streams of flows (e.g., threads in social networks). Accordingly, we modify Pomffyova's (2010) example such that flows are as shown in Figure 8 (in color in online version). In Figure 8, we have the following relationships:

(a) Y1 (dashed lines) deals with the following flowthings:

- Legal issues that flow to his wife, Y2, who is a lawyer, who processes them, then sends them to Y3.
- Employment matters (e.g., salaries and bonuses), which he sends to Y3, Y4, and Y6. For Y5, such matters are sent through Y4.

(b) Y3 (solid lines) deals with sales matters and sends sales data to Y4, Y5, and Y6.

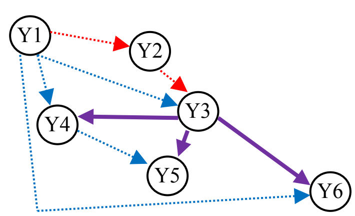

Figure 8: Modified social network diagram.

Figure 9 shows the FM representation of the network depicted in Figure 8. Accordingly, the behavior and importance of each node depend on the flows in which he or she participates. These features influence the importance of the node, which depends on different stages and also on *streams of flow*. For example, Y1 is a *creator* in Bonus streams, while Y3 is a *creator* in Sales. The absence of Y3 (e.g., vacation) would not affect the Bonus flow.

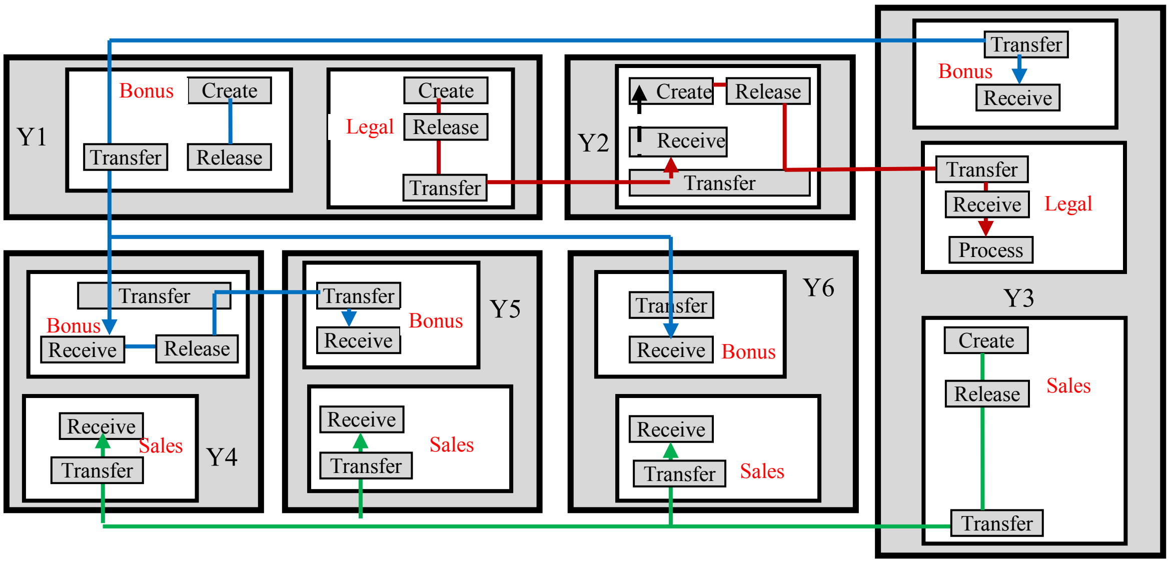

Figure 9: FM representation of the flows shown in Fig. 8.

Bin's (2014) network of Alice, Bob, Carol, David, and Eva and Pomffyova's (2010) small company network (Y1-Y6) are examples that demonstrate how the FM methodology represents a conceptual map of flows among a system of nodes and the transformations of these "things that flow" inside the nodes.

Experimentation

This section explores the use of FM in analyzing the social network site of an online political/social discussion. Two different social networks with different topologies are considered.

Citizenless People Online Social Network

Social networks have provided the opportunity for minorities to organize and be more informed about issues that pertain to them. As a study case, an online social network (OSN) in Kuwait was selected to be analyzed in terms of FM. The network comprises a group of people who are *citizenless*; that is, they have been unable to prove their citizenship over the last fifty years. Specifically, this network is concerned with *citizenless persons* who claim to have Kuwaiti mothers. Their estimated number is 2000, but the network under study consists of 179 members, of which only 37% (66 members) are active (have contributed at least once) and the rest are passive (*registered* members with zero contributions). The network is located at http://q8bedoon.yoo7.com/ Table 1 shows the data collected about the 66 active members. Each member's activities were to determine types of contributions.

Table 1: Data collected about the 66 active members in the citizenless network

Node	Receive		Create		Process		Transfer Output	Transfer (Input + Output)
	From Social Network	From Outside	Original	Replies to messages from others in the network	Receive, Process, and Release (from Internet)	Processed/ Release / Transfer Output		
	A	B	C	D	E	F=D+E	H=C+D+E	A+H
1	934	0	2	0	0	0	2	936
2	935	0	1	0	0	0	1	936
3	934	0	2	0	0	0	2	936
4	934	0	2	0	0	0	2	936
5	932	0	1	3	0	3	4	936
6	929	0	1	6	0	6	7	936
7	935	0	1	0	0	0	1	936
8	933	0	1	2	0	2	3	936
9	933	0	1	2	0	2	3	936
10	792	86	27	31	86	117	144	936
11	904	4	2	26	4	30	32	936
12	814	1	6	111	1	112	118	936
13	861	38	5	32	38	70	75	936
14	792	92	9	43	92	135	144	936
15	902	7	0	27	7	34	34	936
16	927	1	1	7	1	8	9	936
17	926	1	2	7	1	8	10	936
18	891	18	2	26	18	44	46	936
19	935	0	0	1	0	1	1	936
20	883	19	4	30	19	49	53	936
21	934	0	0	2	0	2	2	936
22	915	5	1	15	5	20	21	936
23	864	4	3	65	4	69	72	936
24	934	0	1	1	0	1	2	936
25	933	0	1	2	0	2	3	936
26	898	0	0	38	0	38	38	936
27	935	0	1	0	0	0	1	936
28	933	0	3	0	0	0	3	936
29	926	0	10	0	0	0	10	936
30	935	0	1	0	0	0	1	936
31	935	0	1	0	0	0	1	936
32	935	0	1	0	0	0	1	936
33	934	0	2	0	0	0	2	936
34	934	0	1	1	0	1	2	936
35	935	0	1	0	0	0	1	936
36	934	0	0	2	0	2	2	936
37	935	0	1	0	0	0	1	936
38	934	0	2	0	0	0	2	936
39	935	0	1	0	0	0	1	936
40	935	0	1	0	0	0	1	936
41	930	1	4	1	1	2	6	936
42	933	0	1	2	0	2	3	936
43	917	0	0	19	0	19	19	936
44	928	0	1	7	0	7	8	936

Node	Receive		Create		Process		Transfer Output	Transfer (Input + Output)
	From Social Network	From Outside	Original	Replies to messages from others in the network	Receive, Process, and Release (from Internet)	Processed/ Release / Transfer Output		
45	934	0	0	2	0	2	2	936
46	928	5	1	2	5	7	8	936
47	933	0	3	0	0	0	3	936
48	935	0	1	0	0	0	1	936
49	933	0	1	2	0	2	3	936
50	934	0	1	1	0	1	2	936
51	935	0	0	1	0	1	1	936
52	934	0	0	2	0	2	2	936
53	932	2	1	1	2	3	4	936
54	935	0	0	1	0	1	1	936
55	933	0	1	2	0	2	3	936
56	935	0	1	0	0	0	1	936
57	935	0	1	0	0	0	1	936
58	935	0	1	0	0	0	1	936
59	935	0	1	0	0	0	1	936
60	935	0	1	0	0	0	1	936
61	935	0	0	1	0	1	1	936
62	935	0	0	1	0	1	1	936
63	935	0	1	0	0	0	1	936
64	935	1	0	0	1	1	1	936
65	934	0	0	2	0	2	2	936
66	935	0	1	0	0	0	1	936

According to the FM model, the following types of activities were observed.

Receive (two columns titled *Receive* in Table 1)

This indicator records two types of sources, as shown in Figure 10.

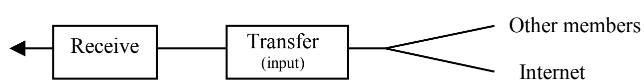

Figure 10: Outside sources of messages

- The left subcolumn (titled *From Social Network*) refers to the number of messages received by the member from other members of the network. This number reaches into the 900s for most members. This is the result of a policy of "sending to all members"; i.e., a member's contributions are sent to all members – accordingly, number of messages received is not important for characterizing the network. If we were to redesign the site, we would install the capability of communicating with subgroups (e.g., a member would be able to send messages to a limited number of followers). Unfortunately, such capability is not available in the system under consideration. We use the number of messages received to determine each member's relative contribution, compared with the contributions of all other members (i.e., a member's level of activity; for example, if a member received a total of 700 messages from the network, and the total number of messages in the network including his or her own is 900, then this means that this member made around 200 contributions (very active).

- The right subcolumn (titled *From Outside*) denotes downloading or copying materials from the Internet.

Table 2 shows members with more than one such activity. Three members made significant contributions: 92 (No. 14), 86 (No. 10), and 38 (No. 13), followed by two members with 18 and 19 contributions.

Table 2: Members making more than 1 contribution from the Internet

Node	Receive		Create	
	From Social Network	From Outside	Original	Replies to messages from others in the network
	A	B	C	D
10	792	86	27	31
11	904	4	2	26
13	861	38	5	32
14	792	92	9	43
15	902	7	0	27
18	891	18	2	26
20	883	19	4	30
22	915	5	1	15
23	864	4	3	65
29	926	**0**	**10**	0
Total		**274**	**63**	

Create (the main column titled *Create* in Table 1)

This involves two subcolumns.

- The subcolumn titled *Original* involves creating, releasing, and sending materials to other members. Table 3 shows that 14 members made zero contributions. Significant contributions were made by three persons, who contributed 27 (No. 10), 10 (No. 29), and 9 (No. 14) items.

Table 3: Created materials

Number of created materials	Number of members contributing
0	14
1	34
2	6
3	2
4	2
6	1
9	1
10	1
27	1

- The subcolumn titled *Replies to messages from others in the network* reflects members who responded to different contributions, as shown in Figure 11. Table 4 shows that 12 members made more than 7 responses.

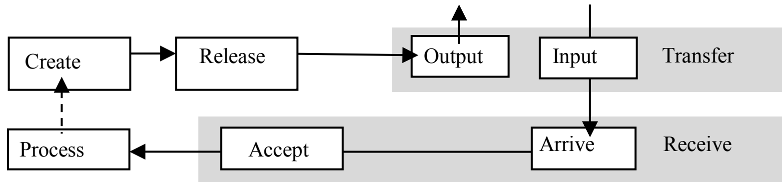

Figure 11: Responses to contributions

Table 4: Responders

Node	Transfer Input/ Receive		Create	
	From Social Network	From Outside (e.g., Internet)	Original / Transfer	Replies to messages from others in the network
	A	B	C	D
10	792	86	27	31
11	904	4	2	26
12	814	1	6	111
13	861	38	5	32
14	792	92	9	43
15	902	7	0	27
18	891	18	2	26
20	883	19	4	30
22	915	5	1	15
23	864	4	3	65
26	898	0	0	38
43	917	0	0	19

Characteristics

After analysis of this network, we made the following observations:

- The majority of the network's contributions (274 of a total 337 contributions) were actually downloaded or copied from the Internet, in comparison with uniquely created materials (63 contributions); see Table 2. Accordingly, the members, in general, can be characterized as "information distributors." They are either unable to express their problems (e.g., have language difficulties), or, probably more likely, afraid to speak their opinions.
- In terms of creating new contributions, we identified one central person (27 contributions; see Table 3) with two supporters (9 and 10 contributions, respectively; see Table 3) backed by two second-level supporters (repliers); see Figure 12. This indicates a single member dominates as a leader. The members seem responsive or empathetic toward only about 38% of active members, with about 12 members being actual respondents (see Table 4).

In conclusion, it seems that this network is characterized by fear, or hesitation to advance their cause, except for a very few activists.

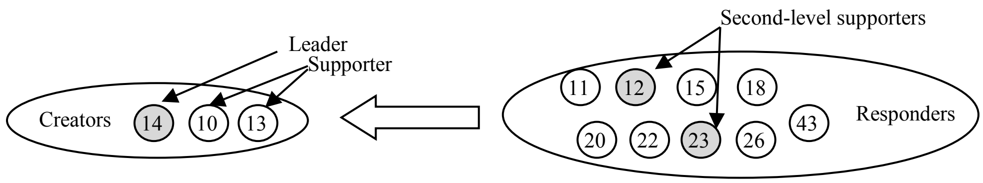

Figure 12: General characteristic of the network

Twitter Network

This is a Twitter network under the thread title (hashtag) "فهد_الرجعان#" commenting about a person recently involved in a financial scandal in Kuwait. Table 5 was constructed by analyzing this Twitter thread. During data collection, messages that did not contain the mentioned hashtag but were shown as replies to original messages of the hashtag were taken into account. It was also noticed that many people who also participated in the discussion of the case did not use the mentioned hashtag but rather some variation or no hashtag at all, especially those users with a very large number of followers.

Table 5: Twitter network

Node	***Transfer Input/ Receive***		**Create**		**Process**		**Transfer (Output)**	**Transfer (Input + Output)**
	In Social Network	***Outside***	**Original**	**Replies to messages from others in the network**	**Receive, Process and Release (from Internet)**	**Processed/ Release / Transfer Output**		
	A	**B**	**C**	**D**	**E**	**F=D+E**	**H=C+ D+E**	**A+H**
2	454	2	0	0	2	2	2	456
3	454	1	0	1	1	2	2	456
4	432	3	15	6	3	9	24	456
8	454	1	1	0	1	1	2	456
10	453	0	1	2	0	2	3	456
21	453	3	0	0	3	3	3	456
22	452	4	0	0	4	4	4	456
23	433	0	17	6	0	6	23	456
24	452	0	0	4	0	4	4	456
27	452	1	0	3	1	4	4	456
29	453	0	1	2	0	2	3	456
32	454	0	2	0	0	0	2	456
34	454	0	2	0	0	0	2	456
36	454	2	0	0	2	2	2	456
37	454	2	0	0	2	2	2	456
38	452	4	0	0	4	4	4	456
39	453	0	1	2	0	2	3	456
41	454	1	1	0	1	1	2	456
42	452	0	0	4	0	4	4	456
43	454	0	1	1	0	1	2	456
44	454	1	0	1	1	2	2	456
46	453	0	2	1	0	1	3	456
47	448	0	0	8	0	8	8	456
48	450	0	0	6	0	6	6	456
49	452	0	0	4	0	4	4	456

Node	*Transfer Input/ Receive*		Create		Process		Transfer (Output)	Transfer (Input + Output)
	In Social Network	*Outside*	Original	Replies to messages from others in the network	Receive, Process and Release (from Internet)	Processed/ Release / Transfer Output		
50	454	0	0	2	0	2	2	456
57	453	3	0	0	3	3	3	456
59	452	3	0	1	3	4	4	456
63	454	2	0	0	2	2	2	456
66	454	0	0	2	0	2	2	456
71	447	0	7	2	0	2	9	456
72	454	0	1	1	0	1	2	456
73	453	0	2	1	0	1	3	456
75	450	2	3	1	2	3	6	456
80	452	2	0	2	2	4	4	456
82	454	2	0	0	2	2	2	456
83	451	1	4	0	1	1	5	456
84	454	0	2	0	0	0	2	456
86	452	0	1	3	0	3	4	456
87	452	0	0	4	0	4	4	456
88	453	0	0	3	0	3	3	456
96	454	0	0	2	0	2	2	456
107	454	2	0	0	2	2	2	456
110	451	0	5	0	0	0	5	456
114	452	0	4	0	0	0	4	456
115	451	0	1	4	0	4	5	456
116	453	0	1	2	0	2	3	456
117	453	0	0	3	0	3	3	456
118	453	0	0	3	0	3	3	456
119	452	0	0	4	0	4	4	456
120	454	1	1	0	1	1	2	456
122	454	0	1	1	0	1	2	456
123	454	2	0	0	2	2	2	456
125	454	0	1	1	0	1	2	456
126	454	0	1	1	0	1	2	456
127	454	0	2	0	0	0	2	456
128	454	1	1	0	1	1	2	456
129	446	2	7	1	2	3	10	456
130	453	0	0	3	0	3	3	456
133	438	1	0	17	1	18	18	456
134	454	0	0	2	0	2	2	456
139	453	0	3	0	0	0	3	456
140	453	0	3	0	0	0	3	456
143	454	1	1	0	1	1	2	456
144	454	0	2	0	0	0	2	456
146	453	0	1	2	0	2	3	456
147	454	0	0	2	0	2	2	456
148	454	0	2	0	0	0	2	456
150	449	0	5	2	0	2	7	456
151	452	0	0	4	0	4	4	456
164	454	0	2	0	0	0	2	456

Node	*Transfer Input/ Receive*		Create		Process		Transfer (Output)	Transfer (Input + Output)
	In Social Network	*Outside*	Original	Replies to messages from others in the network	Receive, Process and Release (from Internet)	Processed/ Release / Transfer Output		
166	454	2	0	0	2	2	2	456
168	453	0	0	3	0	3	3	456
172	454	0	0	2	0	2	2	456
176	452	0	2	2	0	2	4	456
179	454	1	0	1	1	2	2	456
203	454	0	1	1	0	1	2	456
204	454	0	0	2	0	2	2	456
209	454	0	2	0	0	0	2	456
218	454	0	1	1	0	1	2	456
221	454	0	2	0	0	0	2	456
225	453	0	2	1	0	1	3	456

In our analysis we have treated the group of users participating in the hashtag as a single network, reflected in all the related data shown in Table 5; i.e., numbers in the first column, *Transfer Input in Social Network*, refer to the total number of messages exchanged under the hashtag.

The original number of total participants in the researched hashtag is 227, some of whom participated only one time (total transfer out), as either an original message, a reply, or a processed message. These users have been omitted from Table 5 for the sake of brevity, but the node numbers reflect their existence.

Table 6: Top participants

Node	Receive		Create		Process		Transfer (Output)	Transfer (Input + Output)
	From within Social Network	From Outside (e.g., Internet)	Original	Replies to messages from others in the network	Process (from Internet)	Processed Output		
	A	B	C	D	E	F=D+E	H=C+D+E	A+H
4	432	3	15	6	3	9	**24**	456
23	433	0	17	6	0	6	**23**	456
47	448	0	0	8	0	8	**8**	456
48	450	0	0	6	0	6	**6**	456
71	447	0	7	2	0	2	**9**	456
75	450	2	3	1	2	3	**6**	456
83	451	1	4	0	1	1	**5**	456
110	451	0	5	0	0	0	**5**	456
115	451	0	1	4	0	4	**5**	456
129	446	2	7	1	2	3	**10**	456
133	438	1	0	17	1	18	**18**	456
150	449	0	5	2	0	2	**7**	456
Total			64	53		62		

Table 6 shows top participants in the hashtag. The most important characteristic in this partial picture is the number of contributors of original material, approximately balanced by the number of repliers (64 vs. 53, respectively). Two main instigators were identified (numbers 4 and 23), with 11 processors (column titled *Processed Output*), with an average of 62/12 = 5.2 processes.

In general, because of the large number of participants in the network with very low participation rate (see top 12 participants out of 227 users) it seems that this hashtag is used mainly for expressing frustration at corruption in government agencies, with mostly a single comment about the scandal. This shallow contribution indicates very little community debate about the causes and remedies for such a phenomenon, except for a few members (numbers 4, 23, 71, 129, and 150) who made 5 or more contributions; see Table 6). This is also an indication of a pessimistic view regarding prevention of such a scandal in the future.

Conclusion

This paper focuses on characterizing social networks based on the *structural interiority* of the node in order to provide a more fine-grained understanding of social networks. The interior of a node is modeled on the basis of six generic stages: creation, release, transfer, arrival, acceptance, and processing of the artifacts that flow among and within nodes. The method is applied to two actual social networks, and some characteristics of these networks were extracted by examining the internal activities of different nodes. For example, from the low number of *uniquely generated* (created) contributions in the first network, it can be inferred that it is characterized by fear and reluctance to express opinions freely. In the second network, the low level of created and processed contributions indicates that the network's role is to give an outlet for expressing frustration at corruption in government agencies rather than searching for solutions or taking any action against it.

The resultant FM description seems to provide a new methodology for characterizing social networks and points to its viability and potential for further study. An important issue that needs to be addressed is development of a software system that gathers data according to the proposed model flowsystem.

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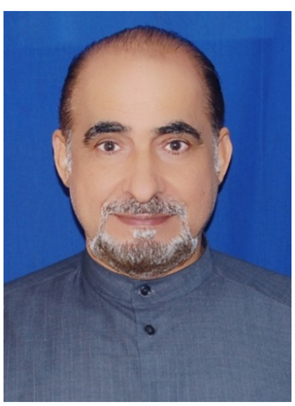
Biographies



Sabah Al-Fedaghi holds an MS and a PhD from the Department of Electrical Engineering and Computer Science, Northwestern University, Evanston, Illinois, and a BS in Engineering Sciences (computer) from Arizona State University. He has published more than 90 journal articles, and over 100 articles in conferences on Software Engineering, Database Systems, information Ethics, Privacy and Security. He is an associate professor in the Computer Engineering Department, Kuwait University. He previously worked as a programmer at the Kuwait Oil Company and headed the Electrical and Computer Engineering Department (1991–1994) and the Computer Engineering Department (2000–2007).

Heba AlMeshari has an MS degree in Computer Engineering from Kuwait University. Her research interests include social networks and software engineering. She is currently working as a computer engineer in Kuwait University.