



# How Information Spreads Through Multi-layer Networks: A Case Study of Rural Uganda

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**Abstract.** The social networks that interconnect groups of people are often “multi-layered”—comprised of a variety of relationships and interaction types. Although researchers increasingly acknowledge the presence of multiple layers and even measure them separately, little is known about whether and how different layers *function* differently. We conducted a field experiment in twelve villages in rural Uganda that measured real multi-layer social networks and then tracked how each layer was used to discuss new information about refugees. A majority of respondents discussed refugees with someone to whom they were connected in the social network. The connections came from all four layers, though the layer indicating regular homestead visits was used most frequently. People did not discuss refugees with every one of their network neighbors; homophily in views, homophily in level of interest, and the alter’s interest in the topic best distinguish links that were used from those that were not.

**Keywords:** Multi-Layer Networks · Discussion Networks · Link Function · Uganda · Refugees

## 1 Introduction

Real social networks tend to be comprised of a rich variety of relationships and interaction types, and hence are “multi-layered” [5, 6, 10, 12, 15]. Scholars studying networks empirically often collect data on multiple layers, such as friends, kin, discussion partners, sources of assistance, and so on [2–4, 11, 16, 18, 20]. These networks are of interest because they likely *do* something—spread information, apply peer pressure, share resources—that matters to outcomes across the social sciences [7, 23, 26].

Understanding how exactly links function is an important step in the process of understanding when and why networks matter [19], especially since certain links may function differently than others. For instance, some links may be based on deep trust, facilitating the spread of sensitive information from person to person, while others may be shallower, only allowing non-sensitive information

to pass through [1, 14, 17]. When links are not interchangeable in their function, researchers need to account for this in their measurement strategy, and aggregating links across layers could be misleading [8, 9, 15, 21, 22]. An important question is then: which links do what and when?

This question is expansive, and a complete answer surely depends on the context in question. A productive way forward would be to amass a collection of studies of link functions in multi-layer networks across contexts. This article contributes one. It focuses on a case which allows deep exploration of the function of different links in the context of rural Ugandan villagers learning new information about refugees.

Specifically, we conducted a field experiment in twelve villages in northwestern Uganda in which we elicited four layers of social networks for all households: who shares meals with whom, who visits whose homesteads, who consults whom in the presence of rumors, and who would turn to whom to borrow money. The study also presented information about the experiences of refugees to a randomly selected half of households. Two weeks later, participants were surveyed again and asked to name the people with whom they had conversed about refugees in the interim. By matching these names with the social network, we can determine whether people used any of the four layers to discuss refugees.

Consistent with previous studies that measure multi-layer networks, we find that the overlap between layers is imperfect and each contributes distinct sets of links and structural features [13, 21, 22, 24, 25]. We find that a majority of respondents did turn to social network neighbors (as opposed to others in the village or beyond) to discuss the new information; in one village, 70% of respondents who talked to anyone did so with a network neighbor. Across villages, discussion partners were connected to the respondent most often in the visit layer (65%), followed by the meal layer (53%), then borrow (44%) and rumor (39%).

Our data also allow us to compare people linked to the respondent in the social network who were named as discussion partners (1212 total links) with people linked to the respondent who were not (6593 total links) to try to understand why respondents made use of the links they did. We consider whether alter characteristics such as personal experience as a refugee, social relationships with refugees, occupation, views on the topic, and interest in the topic matter. Of these, only the alter’s level of interest in refugees significantly differentiates the two groups: alters who see refugees as a very pressing issue are more likely to be named as discussion partners. We also consider whether homophily with respect to religion, language, personal refugee status, views on the topic, and level of interest in the topic matter. Of these, both views on refugees and interest in the topic do: alters who agree on the level of threat refugees pose and the importance of the topic are more likely to be selected by the respondent as a discussion partner.

## 2 Village Networks

We used four name-generator questions in a baseline survey to measure social networks in each of the twelve villages. Table 1 describes the resulting social

network, here represented as the union of the four layers, for each village. Nodes are households, links are directed, and the count of links indicates the number of times one household lists someone in another in response to at least one of the four name generator questions. The table also reports features of these networks, including the mean total degree, the maximum in-degree, the number of nodes who have in-degree or out-degree equal to zero, mean transitivity, and the proportion of households in the largest component.

**Table 1.** Aggregated social network by village

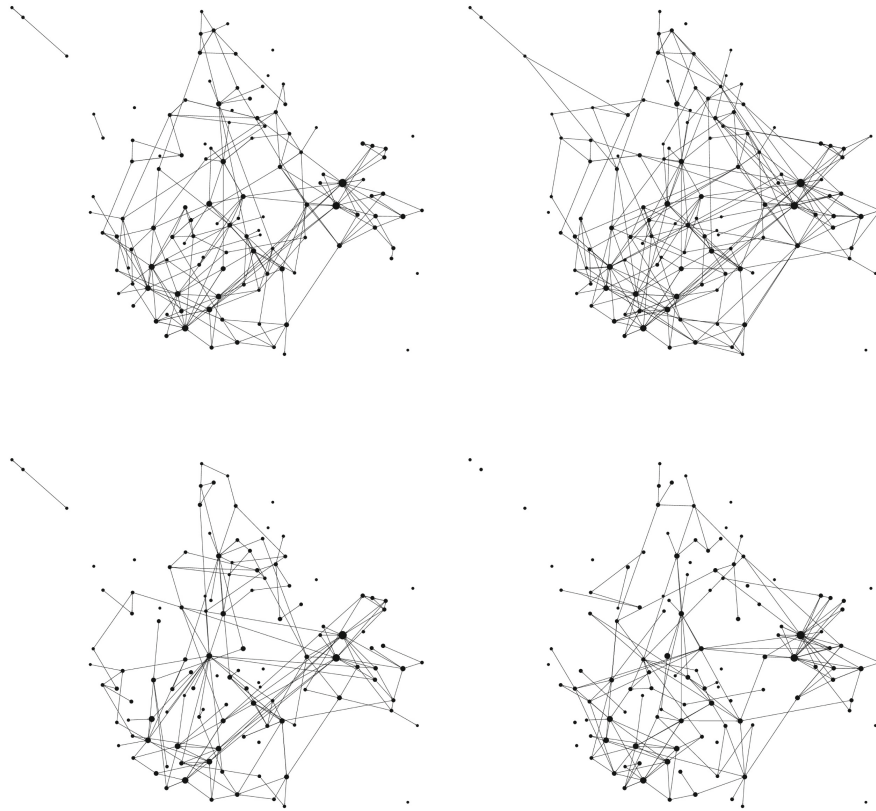
Village	Nodes	Links	Degree	Max In	0 Out	0 In	Trans	Lg Comp
1	132	799	12.11	33	5	12	0.30	0.99
2	114	505	8.86	34	3	16	0.21	1.00
3	148	962	13.00	27	5	13	0.29	0.99
4	125	938	15.01	34	5	18	0.29	0.99
5	163	1030	12.64	31	6	14	0.25	0.98
6	126	692	10.98	28	2	11	0.35	0.99
7	121	456	7.54	23	7	19	0.18	0.99
8	130	437	6.72	17	9	21	0.20	0.98
9	112	803	14.34	33	9	23	0.38	0.96
10	104	364	7.00	12	8	15	0.30	0.99
11	180	492	5.47	23	29	53	0.13	0.96
12	149	327	4.39	24	27	51	0.15	0.89

Table 2 separates the networks into the four layers and reports the same structural features. The values are reported as averages across the villages by layer. On average, a village has 134 household nodes in the network. Each layer contributes differently to the overall village network. The visit layer has the most links on average, though the rumor layer has the highest in-degree—more people point to the same person to vet rumors than to visit in their home. The meal layer has the highest transitivity; households who have members who share meals with the same household are more likely to share meals with one another as well. The borrow layer has the largest number of nodes with out-degree and in-degree equal to zero; many households have no one they would borrow money from, and many households would not be asked.

**Table 2.** Characteristics of each of the four layers averaged over the 12 villages

Layer	Nodes	Links	Degree	Max In	0 Out	0 In	Trans	Lg Comp
Meal	134	298	4.56	11	31	43	0.20	0.87
Visit	134	344	5.23	14	24	38	0.18	0.92
Rumor	134	220	3.31	15	39	57	0.13	0.81
Borrow	134	204	3.10	14	46	64	0.16	0.74

For illustration, we pick one of the villages and visualize the four layers. Figure 1 shows each of the layers for village 7, holding the node placement fixed. Nodes are sized proportional to degree.



**Fig. 1.** The four layers of the multi-layer household network for Village 7. From top left to bottom right: shared meals, visit homestead, discuss rumors, borrow money.

### 3 Use of Village Social Networks to Discuss Refugees

In the second survey two weeks after the baseline, respondents were asked to think back over the past two weeks and name anyone with whom they had a conversation about refugees. Not everyone had done so, though a majority had. Table 3 shows the number of respondents who named any names and also reports this as a proportion of the village’s households. It also shows the proportion of respondents for whom at least one name offered was a neighbor in at least one layer of their village’s social network. We do see variation across villages, ranging from village 11 with 36% for whom this is the case to village 8 with 70%.

We next zoom in on the people who said they did have a conversation about refugees with anyone in the past two weeks. These respondents were invited to name up to five of their discussion partners. The average number of names offered across villages ranges from 2.79 (in village 11) to 4.02 (in village 2).

**Table 3.** Who discussed refugees, were they network neighbors?

Village #	Names > 0	Prop > 0	Any In NW
1	58	0.44	0.64
2	63	0.55	0.63
3	78	0.53	0.67
4	66	0.53	0.56
5	116	0.71	0.62
6	69	0.55	0.64
7	83	0.69	0.66
8	82	0.63	0.70
9	58	0.52	0.64
10	49	0.47	0.59
11	108	0.60	0.36
12	86	0.58	0.40

Table 4 shows the total number of the names respondents offered that also appear as their neighbors in at least one layer of the social network on average across respondents within each village. The four subsequent columns break these totals apart into the number of names that appear as a link in each of the four layers of the social network, reported as an average number of names. For village 1, on average 1.07 people listed are also network neighbors; these people are distributed across the four layers as .43 names in the meal layer, .62 in the visit layer, .38 in the rumor layer, and .47 in the borrow layer. The four layers do not sum to the total number of people because they are not mutually exclusive; a link between a respondent and an alter can appear in more than one layer, so a name can appear in more than one layer for a respondent.

## 4 When Are Links Most Likely to Be Used?

Next we investigate why the links in the network that were used to discuss refugees were in fact used. That is, for each respondent, we know the set of network neighbors across all layers, and we know that some, but not all, of them were selected as discussion partners about refugees. Was the selection random with respect to link, or do we observe differences between used and unused links?

We investigate two sets of attributes of the links. One set centers around attributes of the alter. We might think that alters who have relevant experience,

**Table 4.** Breakdown of discussion partners by layers of network

Village	Total in NW	#inMeal	#inVisit	#inRumor	#inBorrow
1	1.07	0.43	0.62	0.38	0.47
2	1.35	0.81	0.83	0.43	0.67
3	1.18	0.56	0.58	0.41	0.38
4	1.11	0.56	0.70	0.38	0.53
5	1.20	0.53	0.66	0.54	0.43
6	1.13	0.68	0.74	0.25	0.49
7	1.23	0.67	0.89	0.52	0.52
8	1.22	0.74	0.84	0.62	0.51
9	1.14	0.41	0.71	0.28	0.47
10	0.90	0.43	0.63	0.31	0.39
11	0.47	0.24	0.25	0.27	0.19
12	0.63	0.24	0.38	0.36	0.23
Pooled	0.53	0.65	0.39	0.44	

for instance by having been a refugee once themselves (this is true for about a third of our respondents) or who themselves know refugees personally, would be prioritized. Or we might think that alters who have a connection to the land, one of the key resources in question when refugee issues come up, in their occupation as farmers, would be prioritized. Or maybe an alter’s views on refugees<sup>1</sup> or the extent to which she finds refugees to be a pressing issue are important to respondents when selecting discussion partners.<sup>2</sup> Out of all of these alter characteristics, the only one that distinguishes the alters selected from those that are not is the alter’s interest in refugees: links to alters who find the issue of refugees to be more pressing are more likely to be used to discuss refugees.

Likewise, we consider homophily as a possible distinguishing factor between links in the social network used to discuss refugees and those that were not. We consider both religious and language homophily to see if common values or assured ability to communicate are relevant. We also consider shared refugee status, which would be relevant if respondents who were once refugees sought out their network neighbors who also shared this experience (or respondents who have never been a refugee might seek out like neighbors as well). Shared views about refugees, and a shared interest in the topic, could also facilitate conversations. In fact shared interest in refugees distinguishes links used from

<sup>1</sup> Our survey asks respondents to react to the statement “Refugees threaten the way of life in my community” with a five point scale from strongly agree to strongly disagree. Larger values indicate stronger disagreement, and hence warmer attitudes towards refugees.

<sup>2</sup> Our survey asks respondents how important they find the issue of refugees to be on a five point scale. Smaller values indicate greater importance.

those that were not in the network, and shared views does as well, though at a lower level of statistical significance.<sup>3</sup>

**Table 5.** Comparing the links in the multilayer social network that were used to discuss refugees to those that were not.

	Network link used	Network link not used	p-value
Link Count	1212	6593	
Alter was refugee	0.33	0.32	0.55
Alter knows refugee	0.73	0.72	0.37
Alter farmer	0.82	0.81	0.54
Alter's views	3.61	3.54	0.21
Alter's interest	1.36	1.48	0.00
Relig homoph	0.76	0.74	0.11
Language homoph	0.85	0.84	0.46
Refugee status homoph	0.62	0.64	0.41
Refugee views homoph	0.36	0.33	0.08
Interest homoph	0.56	0.52	0.01

Overall, these comparisons paint a picture of villagers using their social network as one source of discussion partners. They do not necessarily discuss the topic with everyone, nor do they necessarily select among their network neighbors at random. Alters in the network who see refugees as a pressing issue are more likely to be discussion partners. Respondents also seem to seek out their alters with whom they agree on the level of importance of the topic and whose views align (whether they are positive or negative). Other attributes of the alter and bases for homophily do not distinguish the used from the unused links (Table 5).

## 5 Conclusion

Villagers in rural Uganda have social networks with four quite different layers when measured in terms of shared meals, regular homestead visits, gossip partners, and borrowing sources. When these villagers are presented with new information, in this case about the experiences of refugees, they do turn to some of these network neighbors to discuss it. Not everyone they turn to is a network neighbor in one of these layers, and not every network neighbor is selected as a discussion partner. The visits layer is the most popular choice— alters selected as discussion partners are more frequently linked to the respondent in the visit layer across the twelve villages, though this layer is also the most dense.

The choice of discussion partner from among the network neighbors appears to be orthogonal to the occupation, refugee experience, and attitudes towards

<sup>3</sup> The p-value reports the result of a two-tailed t-test comparing links used with links not used in terms of the link attribute in question.

refugees of the alter. It also appears orthogonal to shared language, religion, or personal refugee status. Instead, what distinguishes the network links used to discuss refugees is the level of importance that the person ascribes to the topic. Links to alters who find the issue more pressing are more likely to be used, and links to alters who agree with the respondent about the level of importance are also more likely to be used. Shared views about refugees—agreement on the extent to which refugees do or do not threaten the village’s way of life—also predicts link use to discuss refugees, though with less precision.

Overall, these findings paint a picture that in the context of new information about a topic salient to rural villagers in Uganda, social networks play an important role in discussing it. Shared views on the topic and its importance can pave the way for discussion, as can having alters who find the topic especially important. Some layers are used more than others, though all were used in all villages. That no one layer dominates the others suggests that these conversations were not particularly sensitive or rigidly tailored to a certain kind of relationship. The information that would spread as a result is unlikely to exhibit tie-specific diffusion, which indicates that aggregating the layers to understand the consequences of conversations such as these may not mask results to a great extent [21, 22].

Of course these results come from a single instance of network use—discussing new information about refugees—in a single context—rural Uganda. The more cases of networks in action that can be studied in more contexts, the better our understanding of the true role of multi-layer networks will be.

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