Topological Analysis of Criminal Activity Networks in Multiple Jurisdictions

Siddharth Kaza, Jennifer Xu, Byron Marshall, and Hsinchun Chen

Department of Management Information Systems

University of Arizona
1-520-621-2165

{skaza, jxu, byronm, hchen}@eller.arizona.edu

ABSTRACT

Sharing of information between multiple tiers of government is a major focus in digital government research. Law enforcement agencies in particular can greatly benefit from information sharing. Information on known criminals can be analyzed using criminal activity networks that link people and vehicles based on data found in law enforcement databases. We analyze the topological characteristics of criminal activity networks of individuals in a multiple jurisdictional scenario. We find that large narcotics networks are small-world with short average path lengths ranging from 4.5-8.5 and have scale-free degree distributions with power law exponents of 0.85 – 1.3. In addition we find that utilizing information from multiple jurisdictions provides higher quality leads by reducing average shortest path lengths of the networks.

Categories and Subject Descriptors

J.4 [**Computer Applications**] Social and Behavioral Sciences - *Sociology*

General Terms

Measurement

Keywords

Topological analysis, criminal networks

1. INTRODUCTION

Information sharing and knowledge management have emerged as a major focus in digital government research [2]. Government agencies are organized into local, regional, and national tiers with overlapping jurisdictions and closely related missions. In many cases, there is no efficient data sharing mechanism to support the collaborations needed to effectively provide government services like law enforcement. The extraction of Criminal Activity Networks (CAN) is a technique that can be used to analyze information from multiple law enforcement sources in the government. A CAN is a network of interconnected people (often known criminals), vehicles, and locations based on law enforcement records. Criminal activity networks can be large and complex and are better analyzed if we study their topological properties. Topological properties describe the network as a whole and help us better understand its governing mechanisms. They can also be used to quantify the advantages of data sharing to law enforcement. In our research we study the topological properties of, and explore important research questions related to cross-jurisdictional criminal activity networks:

1. What are the topological characteristics of criminal activity networks?
2. How do cross-jurisdictional data affect the topological characteristics of criminal activity networks?

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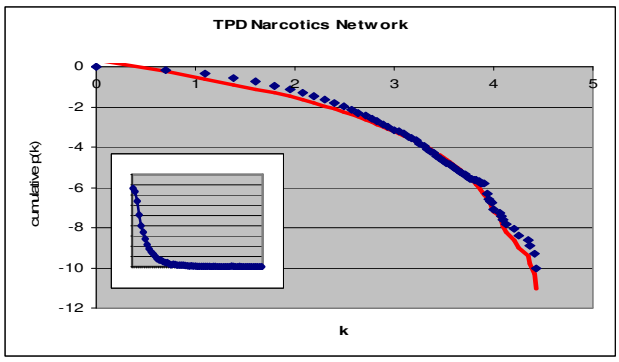
2. LITERATURE REVIEW

2.1 Integration of Information from Multiple Sources

Cross-jurisdictional criminal activity networks contain relationships between entities like people and vehicles that are extracted from many data sources. To triangulate information about an entity, it is necessary to reconcile all the instances of the entity across datasets, which is a challenging task. We use the 'BorderSafe' information sharing and analysis framework [3] for accessing information from multiple datasets. The framework allows us to extract relationships between individuals and vehicles that are amenable to criminal activity network analysis. Details on the process are explained in [3].

2.2 Topological Properties of Complex Networks

Studies of complex real-world networks have explored their topology, evolution, robustness and attack tolerance, and other properties [1]. Networks are broadly classified into *random*, *scale-free*, and *small-world* networks. Three concepts dominate the statistical study of the topology of networks: *small-world*, *clustering*, and *degree distribution* [1]. We study these properties as they have important implications in the domain of law enforcement.



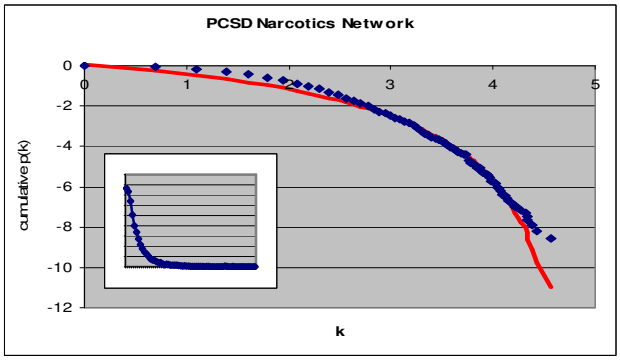


Figure 1. The log-log plots of the cumulative degree (p(k)) vs. the degree (k). The insets are p(k) vs. k. The solid line is the truncated power law curve.

3. RESEARCH TESTBED AND DESIGN

To study CANs we used police incident reports from Tucson Police Department (TPD) and Pima County Sheriff's Department (PCSD) from 1990 – 2002. Border crossing information that includes the license number of vehicles with the date and time of their crossing, provided by Tucson Customs and Border Protection (CBP) was also included in the testbed. This testbed was used to extract narcotics networks that represented individuals and vehicles as nodes and police incidents as edges between them. So, two people have an edge between them only if they are involved in the same incident. We first studied the characteristics of criminal networks in a single jurisdiction. Second, we analyzed the change in characteristics on combining data from multiple jurisdictions.

4. CRIMINAL NETWORKS IN A SINGLE JURISDICTION

Table 1 presents the topological statistics of the narcotics networks extracted from TPD and PCSD records. Figure 1 plots their degree distributions.

Table 1. Topological Properties of Networks in a Single Jurisdiction

	TPD	PCSD
Nodes	31,478 individuals	11,173 individuals
Edges	82,696	67,106
Giant component	22,393 (70%)	10,610 (94%)
Clustering Coefficient (CC)	0.39 (1.39×10^{-4})	0.53 (4.08×10^{-4})
Avg. Shortest Path Length (L)	5.09 (8.80)	4.62 (6.32)
Diameter	22	23
Average Degree, <k>	3.12	4.33
Exponent, γ	1.3	0.85
Cutoff, κ	17.24	16.71

From Table 1 and Figure 1 it can be seen that both networks can be classified as small-world (short *L* and high *CC* vis-à-vis a random network) and have scale-free degree distributions. The short *L* helps law enforcement generate better quality investigative leads [4] and a high *CC* aids the formation of conspiracy cases against criminals.

5. CRIMINAL NETWORKS WITH CROSS-JURISDICTIONAL DATA

Table 2 shows the topological properties of the TPD narcotics network when it is augmented with associations found in PCSD data. No additional individuals from PCSD data were added.

Table 2. Statistics on adding associations found in PCSD data between the individuals in the TPD narcotics network. Values in parenthesis are for the original TPD network

Giant component	27,700 (22,393)
Edges	98,763 (70,079)
Clustering coefficient	0.36 (0.39)
Avg. Shortest Path Length (L)	8.54 (5.09)
Diameter	24 (22)
Average degree, <k>	3.56 (3.12)
Maximum degree	96 (84)
Exponent, γ	1.01 (1.3)
Cutoff, κ	16.39 (17.24)

In Table 2, we see that the size of the giant component in the TPD narcotics network increases. Nodes that were previously thought to be disconnected from the main network got connected. Since we added only associations, it is clear that PCSD contained associations between individuals in TPD that TPD was not aware of. The increase in the number of nodes and associations is a convincing example of the advantage of sharing data between jurisdictions.

6. CONCLUSIONS

This study focused on the topological properties of criminal activity networks in a cross-jurisdictional context. Narcotics networks were found to be small-world in nature with short path lengths and scale-free degree distributions. These topological properties have important implications for security and law enforcement. It was found that a single jurisdiction may contain incomplete information on criminals and cross-jurisdictional data provides an increased number of high quality investigative leads.

7. REFERENCES

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