Spatiotemporal Analysis of 9-1-1 Call Stream Data

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ABSTRACT
Analysis of 9-1-1 call stream data will provide a better understanding of the spatiotemporal patterns of emergency calls, both State-wide and at the local level, and their correlation with external events. Predictive models built with this data can lead to real-time decision support and better overall planning to enable more efficient and effective response to emergencies. While 9-1-1 data is currently being collected across the nation, it is being used primarily for administrative purposes, and not for real-time assessment and prediction of emergency response situations. The objective of this research is to provide that linkage between the data and the spatiotemporal analysis techniques required to mine the data and develop predictive models. This analysis will enable us to detect regular trends versus "unusual" events in the call stream data and establish spatiotemporal patterns and trajectories. Our analysis will include correlation of this information with external event information (e.g. earthquakes and wildfires) to determine spatiotemporal "signatures" of such events. This information then will be used to establish alarm thresholds to provide advanced warning to PSAP's, first responders, and other emergency service personnel, concerning the spatial extent and temporal evolution of an emergency event. Our long-term goal is also to enable the use of this information for real-time detection of emergency events in order to provide rapid response at the local level and facilitate decision support for resource allocation and planning at the State level.

Keywords
Emergency response, public safety, telephone 911.

1. INTRODUCTION
Since the advent of the 9-1-1 system in 1968, massive and ongoing public education campaigns, as well as frequent media attention, have resulted in the widespread recognition and use of 9-1-1. People of all ages and in all locations know to dial 9-1-1 for a medical, fire, law enforcement, or other life-safety emergency. Currently, approximately 98% of the US population is covered by some type of 9-1-1 service. Nationwide, the National Emergency Number Association [http://www.nena.org] provides a forum to foster the technical advancement, availability, and implementation of a universal emergency telephone number system. To our knowledge, California is the only state in the country where 9-1-1 call stream data is already collected at the state-wide level.

2. THE CALIFORNIA 9-1-1 SYSTEM
In California, the 9-1-1 Program is administered by the Department of General Services, Telecommunications Division. Since 1977, this state-wide program has been funded by a surcharge on all intrastate telephone communication services. The State 9-1-1 Program goal is to enable Public Safety Answering Points (PSAPs) to provide expedient telephone access to emergency service for all 9-1-1 callers.

2.1 Enhanced 9-1-1 Call Answering System
A 9-1-1 call is identified by the Central Office (CO) of the local telephone company and routed to a local Public Safety Answering Point (PSAP) where it is answered by an emergency call taker. With Enhanced 9-1-1 (E911), the 9-1-1call is routed to the appropriate PSAP and the caller's telephone number (Automatic Number Identification (ANI)) and location (Automatic Location Identification (ALI)) are displayed to the call taker. Essentially, two database queries are required in the call evolution. First, the CO must determine to which PSAP it must route the 9-1-1 call. Second, the PSAP must determine the originating location (ALI) of the 9-1-1call. The Master Street Address Guide (MSAG) is a critical element of the E911 system and contains the mapping between street addresses and the appropriate law enforcement, fire department, and emergency medical services serving each address. The telephone company subscriber database enables associating a telephone number with a street address.

In California, there are ~20M residential telephones, ~1000 telephone company Central Offices and ~500 PSAPs. The operation of the PSAPs is the responsibility of local government. In California, the major telephone service providers, Verizon and SBC, maintain databases that relate telephone numbers to physical addresses, which is information needed by the ALI aspect of the E911 system. Keeping this information updated is a challenge since there are, on average, ~20% address changes per year.

In addition to providing immediate help by the call taker, the 9-1-1 calls are routed to the appropriate emergency service provider (e.g. law enforcement, fire response, and emergency medical services). There are ~60,000-80,000 landline 9-1-1 calls per day in California and ~250,000 related transactions per day (a single

9-1-1 call typically will result in multiple transactions since calls will be rerouted).

Currently, the California Highway Patrol (CHP) handles most cellular 9-1-1 telephone calls at an additional 24 call centers - a historical artifact since originally most cellular telephones were mounted in vehicles. With the increasing popularity of hand-held wireless telephones, it is likely that these 9-1-1 calls will become the responsibility of the PSAPs as their equipment is upgraded. Nationwide, approximately 33% of the 9-1-1 calls are made from cellular telephones. Federal Communications Commission (FCC) requirements are resulting in the implementation of technology that will upgrade emergency systems to have ANI and ALI capabilities for wireless 9-1-1 calls as is available for landline calls [http://www.fcc.gov/911]. The ALI accuracy will be in the vicinity of 50-150 m. While the FCC mandate for wireless carriers to provide PSAPs with precise location information is set for the end of 2005, it will take somewhat longer until all PSAPs are upgraded and able to display the ANI and ALI data.

2.2 Collecting 9-1-1 Call Stream Data

In California, the State 9-1-1 Program Office in the Department of General Services contracts with Public Safety Network (PSN) to monitor 9-1-1 calls throughout the state. Currently, these data are used only to generate monthly reports for the California Department of General Services, which then uses this information in the allocation of funding for staffing PSAPs throughout the State. PSN captures and stores the following data on all 9-1-1 calls via dedicated telephone lines from each PSAP: (1) the telephone company's identification number for the trunk that delivered the call, (2) ANI and ALI information, (3) the time the call arrived in the back room at the PSAP, (4) the time the call was answered, (5) if the call was put on hold and for how long, (6) if the call was relayed, where and when it was relayed, and (7) the time the call was terminated. In addition, PSN also obtains similar call data from the emergency service providers (e.g. law enforcement, fire response, and emergency medical services).

3. SPATIOTEMPORAL ANALYSIS

The initial phase of this research is focused on understanding the spatiotemporal "trajectories" in the 9-1-1 call stream data via both data visualization and basic statistical analysis techniques.

3.1 Evolution of 9-1-1 Call Stream Data

Anecdotal observations on the nature of the call stream activity indicate that there is a relatively regular daily cyclic pattern with weekends and major holidays differing from weekdays. During a major event, the PSAP capacity eventually saturates and callers are unable to reach a PSAP call taker.

In fact, there are multiple saturation points. First, the telephone system is only designed to handle simultaneous use of a small percentage of telephones installed. Beyond this percentage, dial tone from the CO is not heard by the caller. Second, while the 9-1-1 call might ring at the PSAP, staffing levels might not enable the call to be answered in a timely fashion with the caller eventually abandoning the call. Third, all lines into the PSAP might be in use in which case the caller receives a rapid busy signal. Note that while these latter two conditions might be invisible to the PSAP call takers, the information exists in the 9-1-1 call stream data to recognize when they are occurring

3.2 Environmental and Medical Emergency Events

In California, both wildfires and earthquakes are major environmental events with substantial public impact. Archival information is readily available documenting both wildfire and earthquake activity [http://www.{firescope,cisn}.org]. For example, the devastating Cedar fire ravaged southern California in October 2003 burning 280,000 acres and destroying 2,232 homes. Similarly, a magnitude 6.5 earthquake on 22 December 2003 near San Simeon, CA, caused severe damage in nearby Paso Robles where 40 buildings collapsed or were severely damaged.

A critical component of emergency response is the availability of medical facilities in the immediate vicinity of a disaster event, as well as at a distance for treatment of less-severely injured victims. Although perhaps less obvious, seemingly random treatment of patients in large numbers also could signal an emerging medical event which otherwise would go unnoticed for a period of time until the larger pattern was discovered. In many instances, the treatment cycle begins with a 9-1-1 call.

4. SUMMARY AND FUTURE RESEARCH

Our objectives are to perform spatiotemporal analysis and data mining of the state-wide 9-1-1 call stream data to gain an understanding of the dataset, fuse and integrate this data with other external data sources to uncover relationships with those data, and develop predictive models for spatiotemporal patterns of 9-1-1 calls. Our techniques will identify the "normal" signature in the data versus "unusual" trends and the correlation of both with external events. A systematic and detailed analysis of the 9-1-1 call stream data can help improve emergency management by providing a common operational picture for both state-wide resource allocation and local emergency responders. The 9-1-1 call patterns cut across jurisdictional lines thus capturing an immediate global indication of the extent of an event (which may not be apparent from local agency level information), which then can be used to provide alerts to both the local responders in a region, as well as the OES.

The 9-1-1 call stream data is not currently being analyzed for detection of spatiotemporal patterns, or detection and prediction of "interesting" or unusual trends. Trend analysis of this data can provide indications on whether the system is about to be overwhelmed due to unusual demand - either due to short term events or long term trends tied to other factors (e.g. demographics). This is a valuable raw data source that can be exploited to improve the overall emergency response system by facilitating dynamic resource allocation. Analysis of the real-time call stream data can provide timely assessment of the location and magnitude of incipient disasters. Through more rapid identification and localization of a significant event, emergency response services can be brought to bear earlier and more efficiently thus leading to a more rapid and smooth recovery along with a corresponding reduction in cost.