LOCALIZED DISASTER NETWORKS PLATFORM

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Lately more and more people are getting their up-to-date news bits from social media platforms such as Twitter and Facebook. These platforms add immediacy and transparency to information sharing. They also customize information for each user. Consequently, people prefer these platforms to seek and share information.

Given this appeal of social media platforms along with the ubiquity of powerful mobile devices and the advances in information processing technology, ***if and how can social media like platform help in dealing with disasters?*** Specifically, how can such a platform enable people to automatically be part of pertinent local network, share observations about disasters, provide personalized contextual recommendations to folks in disasters, and possibly improve situational awareness of responders? If such a platform is to be realized, then what challenges need to be addressed?

To answer these questions, let's explore few disaster scenarios along with alternative possibilities.

WHY: SCENARIOS

SCENARIO 1

Justin from New York is visiting Manhattan, Kansas. This is Justin's first visit to mid-west. He arrives at Kansas City via flight on an overcast day and is driving to Manhattan on I-70. Unfortunately, the weather takes a sharp turn and a tornado touches down somewhere along I-70. Here are few possibilities in this scenario.

1. Justin isn't sure how close he is to the tornado. If he is close, then he isn't sure if he is moving towards or away from the tornado.
2. If he is moving closer, then he isn't aware of the safety procedure to be followed in this situation.
3. If he is moving towards a segment of I-70 that was struck by the tornado, then he isn't aware of the detour to avoid the wreckage (and clear the way of responders).
4. If he was injured in the tornado, then he doesn't know the location of the nearest emergency medical center where can get help.

Clearly, a chaotic and scary scenario.

WHAT IF?

Now consider the same scenario with these alternative possibilities.

0. When Justin turns on his mobile phone after landing in Kansas City, app X on his phone chimes to inform that it has received information about safety procedures for area specific disasters such as tornadoes and flash floods. Justin reads this information while checking out his rental car.

While Justin is driving to Manhattan on I-70, a tornado touches down somewhere along I-70. Folks who caught a glimpse of the tornado share this information with system Y via app X on their mobile device. (Instacane provided a storm photo aggregation service when Hurricane Sandy hit New York 2012.)

1. Based on Justin's current location, app X on his phone informs him that he is 10 miles from the tornado.
2. Based on his recent trajectory along I-70, app X informs him that he is moving closer to the tornado. Based on his current location relative to the tornado, it recommends that Justin stop and take shelter under the next overpass, which is 2 miles down the road. It provides detailed instructions about what to do after stopping at the overpass, e.g., which part of the overpass should Justin take shelter under.
3. If Justin is driving towards a segment of I-70 that was in the path of the tornado, app X automatically shows an alternative route to avoid the wreckage and clear the way of responders.
4. If Justin indicates to app X that he is hurt, then app X provides directions to the nearest emergency medical center along with any other pertinent information. If Justin indicates that his condition is dire, then app X informs responders of his condition and location and, may be, connects them to Justin via a phone call.

In the what-if version of this scenario, information gathered by system Y from various people via app X can be used by responders to

- prioritize response to affected areas based on criticality of the effect in various areas,
- draw out a more precise plan of assistance,
- coordinate better with local authorities to set up assistance centers,
- identify any special needs of folks in the affected areas,
- be aware of any pending and developing issues in affected areas, and
- share information (either proactively or on demand) about affected people with families.
- Reduce the scale of needed disaster response through diverting possible victims into safe zones.

System Y and app X can also be used by responders to provide affected people with precise advice to help themselves until help arrives and up-to-date information about the disaster and actions being taken to assist affect folks.

SCENARIO 2

Due to continued heavy rains over the past few days, the spillway of a dam in California has been open since afternoon and this has led to a possible flooding situation. Here are few possibilities in this scenario.

1. Jose lives upstream along the spillway. While returning home after midnight, Jose sees the flood water break the bank. He wants to inform his neighbors and folks living downstream but he does not know of the best channel to inform them.
2. As precaution, the local officials are recommending all folks downstream along the spillway to evacuate to avoid a possible flooding situation. Erin who lives downstream along the spillway would prefer not to evacuate until the flooding situation is confirmed but she doesn't know if such information will be available and how to access that information.
3. Next day, Xu observes the tap water is brown in color. She would like to confirm if this is an issue only in her house or if it has observed in other houses in her locality. Her options are to call her neighbors or her friends who live a couple of blocks away or the local municipality. Further, she isn't sure if and how should she handle the situation.

WHAT IF?

1. As soon as Jose sees the flood water break the bank, he shares this observation with system Y via app X on his mobile phone. System Y shares this information along with evacuation procedures with folks in the immediate vicinity via app X. It also informs responders and local authorities about the incident.
2. After considering latest updates, available information about the landscape along the spillway, and the locations of houses downstream, System Y uses app X to inform Patty that she is not in immediate danger from flooding but she should be prepared. It provides latest updates and advice on how to evacuate, if needed.
3. After testing water in various faucets of her house, Xu fires up app X to report this incident. She sees that others have reported similar incidents and are discussing possible ways to handle the situation. She reports her observation. System Y informs city municipality of the reported incidents. City municipality uses the locations of reported incidents to quickly identify possible locations to fix the situation. It also used system Y and app X to instruct residents on how to handle the situation.

SCENARIO 3

On a pleasant afternoon, there are shootings in DollyBrook mall in Tennessee. Here are few possibilities in this scenario.

1. Mel sees and hears the shooter fire shots. She is petrified and calls 911. After the call, she wants to inform others in the mall about the shooter but she does not know how to inform them without putting herself at risk.
2. Folks hear big bangs and they cannot decide if they should leave the mall or continue shopping. More importantly, if they decide to exit, then they do not know the emergency exits nearest to them.

WHAT IF?

1. Mel uses pre-defined disaster report feature of app X to rapidly indicate that she is in a shooting situation.
2. Upon receiving disaster report, system Y immediately sends push notifications to app X on mobile phones of folks in the local vicinity about the situation. The notification includes safety procedure to follow in the situation along with information about nearest exits and directions to get to these exits.
3. Other onlookers like Mel report the disaster via app X. Based on the origin location of disaster notifications, responders quickly narrow down the exact location of the shooter in the mall. This helps them get a good estimate of how folks are distributed relative to the shooter. This helps them develop an accurate plan of action for evacuating the mall and handling the shooter.

WHAT: SOLUTION

WHAT IS COMMON ACROSS THESE SCENARIOS?

Some form of *disaster* is a common element in the above scenarios and it triggers various communication and information dissemination problems in these scenarios. However, there are equally or more interesting elements common to the solutions to these problems as highlighted in the what-if version of the scenarios.

1. Sharing immediate experiences and observations.
2. Providing contextual and personalized information.
3. Community involvement to improve safety and agility during disasters.
4. Using geo-local temporal networks to facilitate sharing of pertinent information.
5. Using information technology (e.g., mobile, AI) to facilitate situational awareness via information sharing before, during, and after disasters.

Various agencies (e.g., NOAA, FEMA / NIMS, Red Cross) and policies (e.g., NRF, ICS) exist in the US to respond to disasters and they have clear prescriptions for how to disseminate information to the public (top-down). However, there is no clear prescription for how to consider and integrate input from the local community into the disaster response process (bottom-up). Until recently, people have resorted to various broadcast systems such as radio and TV to get current information about a developing situation. Nowadays people resort to social media platforms such as Twitter and Facebook to get such

information. This is evident in recent incidents that occurred in public space, e.g., school shooting in Los Angeles, Oroville dam incident during rains in California, Hurricane Harvey making landfall in Houston. In fact, news broadcast agencies have now started using social media platforms to get additional current information about developing situations.

WHY NOT USE SOCIAL MEDIA PLATFORM?

The tech savvy might immediately suggest "why not extend social media platforms with capabilities to enable the above possibilities, like the Facebook "I'm safe." feature?" While this is a possibility, it is not an immediate and direct fit for the problem. Social media platforms are built to enable users to maintain networks/cliques of people based on their social disposition independent of other constraints such as geographical or temporal proximity. Also, the information catered to users is controlled by the clique (and, to an extent, by the social media platform). Further, social media platforms are intended for general settings with very little constraints/requirements. Consequently, the data in social media is often too general, unstructured, and largely context-insensitive, e.g., tweets often do not contain origin location information, tweets are not catered based on viewer's current location.

In contrast, the cliques in the above scenarios (e.g., all people in the DollyBrook mall at the time of the shooting) are determined by the location (and the situation) of the users independent of the preference of the users in the cliques. Further, these cliques of people are dynamic and continuously evolving as people move, e.g., as Justin was driving on I-70 in scenario 1. In addition, the system (i.e., system Y) that facilitates such networks is intelligent to consider information from users, aggregate them in a location, time, and event sensitive manner, and provide personalized and contextual recommendations to users. Consequently, such a system is dedicated/specific to tackling disastrous events (like amber alert) with supportive constraints/requirements, e.g., app X will always geo-tag event reports.

SOLUTION

A simple version of such a disaster network platform can be viewed as *Waze for Disasters* – a localized, personalized geo-temporal dynamic support network. It would be comprised of an *app X* that runs on network enabled mobile devices often carried by people and a central *system Y* that collects and processes information from installations of app X and other information sources (e.g., NOAA) to provide contextual recommendations. Any person with a mobile device can be part of the local network (clique). User installs app X and uses it as described above in various scenarios. While SMS/MMS can be used to share experiences/observations, push notifications supported on most mobile platforms can be used to provide recommendations. System X can either be supported by the state (like 911 system) or by paid subscription. A richer version of the platform can use and contribute to other information sources, e.g., weather service, various agencies, social media platforms, and sensor networks.

A more advanced version of such a disaster network platform can be viewed as *Craiglist for Disasters* that enables individuals (and agencies) to exchange information about needs and available resources and automatically matches available resources to needs while considering the local context.

If these scenarios/use cases seem whimsical, then Hurricane Sandy and Irma provide concrete evidence that they are not whimsical. During Hurricane Sandy, people explored and resorted to focused makeshift solutions to exchange information, e.g., storm photo aggregation. Also, there was a need to exchange information about needs and available resources, e.g., power sharing. During Hurricane Irma, Florida Governor asked citizens to use mobile apps and online services to find needed resources.

This figure illustrates how disaster networks operate and how they differ from social networks.

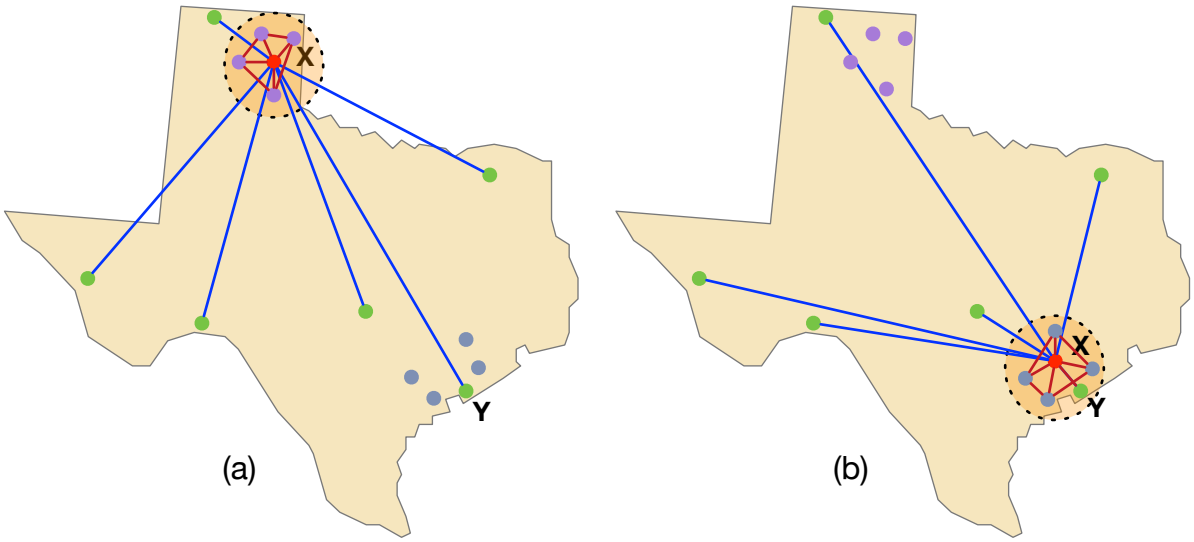

Figure 1

Figure 1.a and 1.b depict user P with app X (denoted by the red dot) being in different locations at different times. At the current location of user X, she automatically becomes a member of the local disaster network/clique (denoted by red edges)[1] that is composed of all users local to user X's current location; say, within a specific radius of user X (denoted by the orange bubble). As user X moves, her local disaster network/clique is dynamically changes according to her location. The locality used to define a disaster network may vary in size – street, city, county, state, region, or country, i.e., the size and shape of the orange bubble may change. Also, disaster networks may be organized as a hierarchy where networks higher up in the hierarchy cover larger geographical areas and possibly facilitate flow of information between different sub-networks.

In contrast, in both locations, user X belongs to the same static social network/clique (denoted by blue edges) independent of his/her location. Further, user X controls who is part of her network and there is no obvious hierarchy of networks.

Notice that when user X moves closer to her friend user Y, users X and Y belong to the same disaster network. This introduces some connection redundancy that can be useful during times of disaster.

In short, social networks are sensitive to social relationships and (mostly) insensitive to user location while disaster networks are insensitive to social relationships and sensitive to user location.

[1] For simplicity, only few connections in the networks are shown.

HOW: CHALLENGES

While many pieces required to realize the proposed disaster network platform exist today (e.g., social networks [Facebook, Twitter, Instagram, Snap Map], centralized information aggregation/distribution solutions [Amber Alert, ReadySD, CivicReady, HarveyRelief], mobile connectivity [mobile phones, wifi hotspots]), there are quite a few unique and diverse fundamental issues that need to be addressed to realize the platform. Here are few such issues in the form of questions grouped by closely related research areas.

- Intelligence
    - Which event report is related to a disaster?
    - Based on the event reports seen so far, what is the disaster? Is it current?
    - When is the best time to inform the locality about the disaster?
    - What should be the personalized and contextual recommendations for user M, e.g., slow mobility, bad vision, hour of the day?
    - How should other information sources (e.g., NOAA, DOT) be considered to arrive at recommendations?
    - What should determine the flow of information across different networks/cliques?
    - In post-disaster situations, how can reported needs be matched to available resources, e.g., electricity needs matched to close by folks with electricity from solar panels?
- Social
    - Why should an event report from user M in his locality be trusted?
    - Why should an event report from user M in another locality be trusted?
    - Which clique does a user belong to, e.g., area within certain radius?
    - How do various aspects such population density and speed of disaster affect clique formation/dissolution and, consequently, information dissemination?
- Security & Privacy
    - Who is a user – person or device?
    - What information identifies users?
    - Who can access user information, e.g., identity, history?
    - Who influences the provided recommendations? To what extent?
    - How is the network resilient to cyberattacks?
- System & Algorithms
    - What technologies, infrastructure, and algorithms are required to support the scale and almost real-time responsiveness required of the platform?
    - How does the system model and automatically reason about a rapidly changing giant network?
    - How can people without mobile devices be supported?
    - How does the system operate under limited connectivity, e.g., cell towers are knocked out?

- Built Environment
    - What architectural, infrastructure, and geographical features can be considered to provide timely and effective disaster assistance? How can such information be used to provide helpful safety guidance until assistance arrives?
    - What policy-related geographic information (e.g., FEMA flood map, US severe weather map, FHWA work zone, land use, etc.) can be considered to provide timely and effective disaster assistance? How can such information be used to provide helpful safety guidance until assistance arrives?
    - What geographic information system (GIS) technologies are required to support spatial and geographic data on the platform?
    - How can people collaborate to create and utilize editable geographic information (say, via services like OpenStreetMap) to contribute to the platform?

Beyond the challenges, such networks can provide data to explore questions pertaining to social behavior, infrastructure, and urban communities. Here are few interesting questions it can help answer.

- Social Behavior
    - How does human behavior in social networks differ from human behavior in ad-hoc disaster networks?
    - How does such networks affect human behavior at the time of disasters? Does it differ across different kind of communities, i.e., rural, suburban, and urban?
- Infrastructure
    - How well does our current communication network assets (e.g., cell towers) support such disaster networks?
    - What changes to communication network assets would make disaster networks more robust?
- Urban Communities
    - How can such localized disaster networks help enhance social capital of urban communities in disaster response?
    - How can such networks help make communities more socially-connected even in poorly-connected built environment (such as car-oriented suburban areas)?
    - How can urban planning and design principles be adapted to enable such networks?
    - How can urban planning and design principles leverage the benefits of such network to build better communities?