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Shelter: Smartphone Bridged Socialized Body Networks for Epidemic Control

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Shelter: Smartphone Bridged Socialized Body Networks for Epidemic Control
(invited paper)

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We propose using information, computing and networking innovations to tackle epidemic control challenges.

1. Motivation

The explosive growth of human mobility and social structure complexity in the past century, accompanied with population increment, has led to a variety of new problems related to public health. As a prominent challenge, the high density of people and their intensive social interaction lead to a significant risk of epidemics. This was evident in the recent outbreak of SARS, H1N1, and H5N1. Besides the high risk of natural disease, such social reality and trend also result in a significant risk of human initiated bio-terrorism events, such as a smallpox based bio-terror attacks [1].

Outbreak and epidemic control requires swift and accurate action. However, the existing approaches are far from sufficient, because they can not support ***real-time critical information collection and analysis***. They are the key to the success of accurate online decision making since evolution or mutation can happen in virus and pathogens [2] and social structure can change during an outbreak.

Here, real-time critical information denotes the information that is time-variant and critical to disease spreading. It includes the health condition of individuals, external environment, and social structure, etc. Real-time critical information based analysis denotes accurate characterization of disease epidemiology, prediction of trends, and evaluation of the projected impacts of different measures.

Unfortunately, real-time critical information collection and analysis remain difficult; in the past, scientists and policy-makers have often failed to make and adjust policy in real time [3].

2. Shelter System

Our Shelter (**s**martp**h**one bridg**e**d socia**l**ized body ne**t**works for epid**e**mic cont**r**ol) system has two functionality blocks; one is for critical information collection, the other is for critical information analysis.

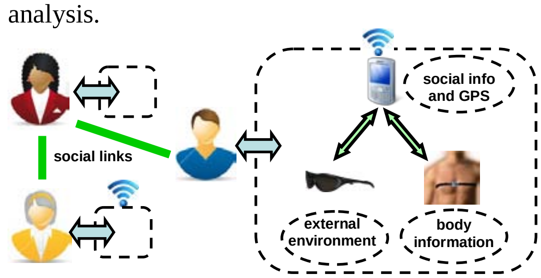

Figure 1. Critical information collection in Shelter

As illustrated in Figure 1, the information collection component in Shelter system is designed by ***seamlessly fusing body mounted sensor networks and smarphone systems***. It works as follows:

1. Smartphones collect social information. Such information includes, but not limited to, physical contact information (e.g., with whom and how long) and movement pattern.
2. Body mounted sensor networks collect body information (e.g., body temperature, blood pressure, heart rate, blood oxygen saturation) and external environment information (e.g., temperature, humility, barometric pressure, pollution level).
3. Smartphones also assist sensing body behavior or gesture information (e.g., jogging and running) and external environment information (e.g., by barometer).
4. Smartphones act as the local control center of body mounted sensor networks.
5. All sensed information will be sent to smarphones for possible preprocessing and then be uploaded to the control center.

We use smartphones as important devices (solution) to fuse the social information collection and information collection by body sensor networks because:

1. Mobile handsets, including smartphones, have become increasingly ubiquitous and feature-rich in the last ten years. We envision that this

trend will continue.

2. Communication features such as Bluetooth and Wi-Fi enable smartphone users to directly connect with each other without requiring signal coverage from base stations. The costs to build additional infrastructure for mobile social networking is reduced, which makes our system more feasible.
3. The accelerometers, GPS systems and other sensors embedded in smartphones provide users with the capability to detect surrounding people and objects with increasing accuracy and completeness (e.g., motion detection by accelerometers and people's localization by GPS systems).
4. Smartphones are becoming affordable to most of people. The cost for purchasing a smartphone has gradually decreased and will continue to decrease.

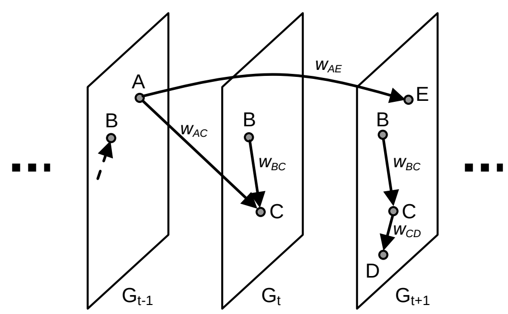

Figure 2. Critical Networks for analysis in Shelter

To capture the real-time critical information, we introduce a new concept: ***Critical Networks***. We use the example shown in Fig. 2 to illustrate the concept. The elements of critical networks are nodes, arcs, and a series of planes. A node represents a user of our Shelter system. Each node can be white, gray, or black. White nodes denote people who have never been infected and are healthy; grey nodes denote people who were infected but now have already recovered; black nodes denotes people who are infected and have not recovered yet. An arc between two nodes represents the infection relationship; the node pointed by the arc is infected by the one that originates the arc. We also define weights (using G-causality) on each arc to indicate how much in terms of possibility the node at the head of arc can affect the node at the tail of the arc. A plane represents the above information during one time period unit, which can be considered a *snapshot* of the critical networks.

In Fig. 2, snapshot G_{t-1} indicates the states and relationships of different nodes during time (day) t-1: node A and B are both black (sick) nodes. In snapshot G_t, node A recovered (become a white node and not shown in Fig. 2 for simplicity) and node B is still sick. We note that there appears a newly infected node C. C is originally a white node. It contacted A in G_{t-1}, but not got sick in G_{t-1} due to the latency and incubation nature of epidemic disease. In G_t, C also contact B. The infection of C can be the result of contact with A and B both or one of them. Such possibility is reflected by weights w_{AC} and w_{BC}. In snapshot G_{t+1}, C infects white node D with weight w_{CD}. Meanwhile, node E is sick due to its contact with A two time period units (days) early.

The critical networks enable recording the real-time critical information. It not only records the isolated snapshot information, but also records the causal relationship between different snapshots (time series). We let each node associate with a vector, which contains the states, i.e., sensed information by body mounted sensor networks, of the corresponding person at different timestamps. The arcs and their weights are calculated by integrating these states and social information such as contact and movement patterns, etc.

Based on critical networks, we can do prediction and implement strategies for epidemic control in the control center. Decisions or alerts or behavior guides that are generated by the control center will be pushed back to smartphone users.

4. Final Remarks

The proposed Shelter system, by filling the dual gaps between social information collection and body including external environment information collection, and between critical information collection and critical information analysis, provides a promising solution for real time epidemic control.

Meanwhile, it raises several research challenges that need innovative solutions: 1) how to effectively and efficiently collect accurate social information, 2) how to design power saving schemes at no much cost of data collection, 3) how to efficiently and accurately present, interpret, and use of collected data, and 4) how to design fast and robust algorithms for conducting prediction and developing real-time strategies. These challenges guide our on-going and future research directions.

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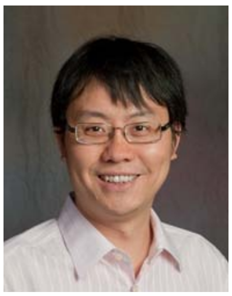

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Hua Fang is an Assistant Professor in Division of Biostatistics and Health Services Research, Department of Quantitative Health Science. She received her Ph.D degree in Ohio University, 2006, specialized in computational statistics, pattern recognition, research design, statistical modeling and analyses in clinical and translational research. Her research involves developing innovative methods and applying emerging robust techniques to enable or improve health studies. She won Layman Awards for missing data modeling and growth trajectory pattern recognition in 2008. She won a paper award at the 2006 Joint Research Conference on Statistics in quality industry and technology. She has been the investigator, biostatistician, leading methodologist of NIH-funded grants, currently a NIH CTSA CER Key Function Committee member in Methods workgroup. She has been a statistical consultant in health, medicine, and bio-engineering areas for multiple years.