Demo Abstract: Safety Assurance for Archeologists Using Sensor Network

Shan Chang[1] Qingxi Li[2] Yong Qi[1] Jizhong Zhao[1] Yuan He[2] Xue Liu[3]
[1]Xi'an Jiaotong University, China [2]Hong Kong University of Science and Technology [3]McGill University, Canada

Categories and Subject Descriptors
C.5.3 [**COMPUTER SYSTEM IMPLEMENTATION**]: Microcomputers – *Portable devices*

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1. INTRODUCTION
Wireless sensor networks (WSN) are proliferated in the recent years. Applications of WSNs spread across many different areas, including scientific observation, environmental monitoring, health care, and military surveillance [1, 2]. Our work is motivated by the safety requirements of many team-oriented activities, such as mountain climbing and archaeological activities. Archeological activities usually involve a team of cooperative archeologists working dispersedly in complex and potentially dangerous environments. Complex terrains, low visibility, and bad weather conditions in those environments are threats to the safety of archeologists. Therefore, team members must keep in contact and get notified of dangerous situations in real-time to ensure safety. Walkie-talkies can be used for communications, but they cannot provide the location information that is important for safety assurance. In most complex environments, GPS-enabled devices cannot function either.

To address the above challenges, we propose a novel scheme applying WSNs in the safety assurance systems. The safety of archeologists includes the following perspectives: 1) to avoid every team member being a straggler; 2) to prevent the team from being partitioned; 3) to properly assign relative positions for the team members in the whole team for reliable communication and cooperation. Our design named SaSa employs a WSN which consists of sensors and PDAs carried by the archeologists. Basing on the sensory data, the status of every archeologist is actively monitored. SaSa can also estimate the locations of the archeologists by simply utilizing the network information from the WSN, without any additional equipment like GPS. SaSa supports safety evaluation through the analysis of the global topology information. In addition, it can notify the others for help when a team member falls in danger.

2. DESIGN
The design is described as follows: In a team of archeologists, each leader is equipped with a PDA and each member is equipped with a wireless sensor. The PDAs and sensors form a wireless mobile sensor network, with the PDAs as sink nodes, as shown in Fig. 1. The WSN is modeled as a graph $G = (V, E)$, where V denotes the set of nodes, and E denotes the edges between nodes. There is an edge between two nodes if the two corresponding sensors can communicate with each other. By maintaining and analyzing the topology of the graph, SaSa can evaluate the safety of each member, and detect team partitions. It can also offer various analytical results about the topological characteristics of the network, assisting an archeology team in selecting proper safety strategies.

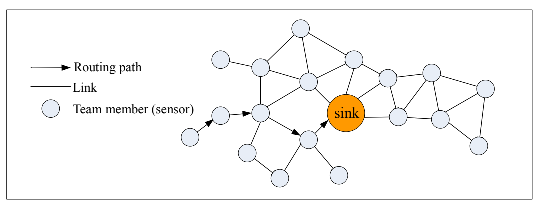

Figure 1. Architecture of SaSa

2.1 Safety Evaluation for a Single Member
As a fundamental safety requirement, an archeologist must keep in close touch with a certain number of team members to make sure he/she doesn't straggle behind. When he/she gets in trouble, the other team members in the vicinity can receive distress signals instantly and offer first aids. Correspondingly, every node in the graph G has a minimum degree of n. The value of n is pre-configured, depending on the risk level of the current archeological environment. A sensor node can monitor its degree locally. If the degree falls below a specified value, a warning signal is generated to notify its owner the potential dangers.

2.2 Detection of Team Partitions
Due to the different speeds and directions of the members' movements, the whole team might be partitioned into multiple sub-teams. As a result, members belonging to different sub-teams cannot communicate with each other

and the leader cannot coordinate the team actions. From a topological viewpoint, this situation corresponds to the case that graph G is partitioned into multiple disconnected sub-graphs. SaSa can detect the graph connectivity, identify *bridges*, and help to maintain k-edge-connected graphs. The specific value of k is application-determined, relying on the safety strategy in a given archeological environment.

We adopt two types of detection methods, centralized and local detection algorithms. The centralized algorithm uses probing messages issued from the sink to detect team partitions. The local algorithm proposed in [3] is triggered on every node that cannot receive probe messages from the sink, so that the connectivity of the local network around the node can be examined.

2.3 Analysis of the Topological Characteristics

SaSa can provide a variety of analytical results of the topological characteristics of a sensor network. Here we illustrate the usage of two types of characteristics in SaSa.

2.3.1 Centrality

In graph theory, the centrality of a vertex determines its relative importance in the graph. In SaSa, this index implies the importance of the position where the corresponding archeologist is. SaSa provides three measures of centrality: degree, betweenness, and closeness. Basing on the measured centrality [4], the team leader can adopt certain team strategies to assure safety. The definition and usage of those centrality indices are briefly introduced below.

Degree centrality: The simplest centrality is defined as node degree. We use this index in section 2.1.

Betweenness centrality: Intuitively, vertices that occur on many shortest paths between other vertices have high betweenness centrality. Team leaders can appoint veterans to the positions which have maximum betweenness, because those positions are most critical in the team.

Closeness centrality: this index gives higher values to more central vertices in a graph. Team leaders can appoint jackaroo to the positions which have maximum closeness, because they are in the center of the team and comparatively safe.

2.3.2 Diameter

In SaSa, the diameter is defined as the maximum hop counts between two arbitrary nodes. Team leaders know the number of members in the team. By measuring the diameter of the team online, they can select proper strategies to avoid the whole team from getting too long and narrow, result in difficulties of team leaders to handle.

3. DEMONSTRATION TESTS

In this demo, we deploy a laptop (to emulate the PDA carried by the team leader) and 9 TelosB-2420 sensor motes. This mimics a team of 10 participants: the team leader carries the laptop, while the rest are ordinary members equipped with sensor motes, as shown in Fig. 2.

Figure 2. Demonstration setup

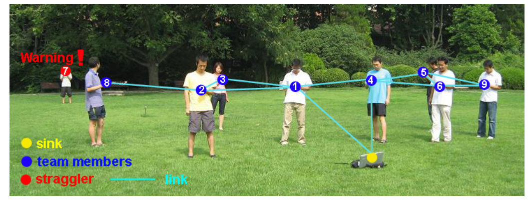

Figure 3. Detection of stragglers

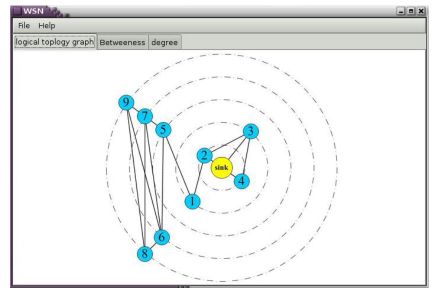

Figure 4: The visualized topology on the sink

First, we tune the sensors' transmission power to construct a multi-hop WSN on a lawn. The participants are then asked to move around to simulate different safety-violation patterns. The demo includes three parts: (1) Detection of stragglers, as shown in Fig. 3; (2) Detection of team partitions; (3) Visualization of the detected topological characteristics of the WSN, as shown in Fig. 4, which is corresponding to the scene in Fig. 2.

4. ACKNOWLEDGMENTS

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