Establishing Network Connectivity under Rubble Using a Hybrid Wired and Wireless Approach

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***Abstract*—**Under rubble communication is a well-known difficult problem. This is due to a number of inherent difficulties including plentiful and diverse physical obstacles that challenge both wired and wireless communication. Our previous work has shown that it is possible to use Urban Search and Rescue (USAR) dogs to deliver emergency supplies, robots and surveillance equipment to a patient trapped in rubble. As a continuation of this work, we propose a novel approach for establishing a line of communication between rescuers and trapped victims via a hybrid wired and wireless network. The delivery method utilizes rescue canines to automatically deploy a communication node upon locating a patient. The communication node is a WiFi access point with a tethered connection to an exterior command centre. Our preliminary results demonstrate that it is possible to establish two-way audio and video communication with a simulated patient using a human-delivered tether. Future experiments will test the efficacy of canine delivery.

***Keywords*:** *WiFi, wireless, wired, network, rubble, canine delivery, USAR*

I. Introduction and Background

Good communications are vital in an Urban Search and Rescue (USAR) operation. A good communication network allows information to be disseminated quickly and effectively among first responders. At incidents involving substantial structural collapses, many parts of the new rubble environment are usually dangerous, physically challenging and wireless communications limited. As large urban structures are largely made of steel reinforced (rebar) concrete, the resulting rubble from a collapse often forms extensive pockets or voids which are difficult to extend a wireless network into and provide the additional physical challenge of actually traversing them while conducting search operations. Deploying a communication network in rubble is a well-documented challenge. Seminal work in [1] discusses the challenging communication environment at the Collapse of the World Trade Center towers.

Indeed, establishing a communication channel between rescuers and patients can have a significant impact on rescue efforts as reported in [2]. A patient can potentially survive for a longer period of time with the distant guidance of a medical doctor communicating with them. In addition to physical injuries, patients can suffer from psychological trauma [3]. It was suggested that intervention is needed within-incident to provide a protective effect against Post Traumatic Stress Disorder [4].

We have previously reported the use of the Canine Remote Deployment System (CRDS) [5, 6] to deliver emergency supplies to trapped patients in rubble. An extension of this research explored the possibility of deploying small robots around a trapped victim [5, 7]. An assumption of our work has always been that there is an existing wireless network in place as the robot or other equipment carried by the dog was assumed to be wireless. How that network was deployed was outside the scope of that research.

To address the network creation problem of establishing communications between rescuers and trapped patients we propose using a hybrid approach employing wired and wireless networks as suggested in [8]. This paper describes our preliminary investigation of a system developed to establish communications through the delivery of appropriate equipment by dog. The system--Canine Automatic Network Extension System (CANES)--utilizes search dogs to automatically deploy a communication node upon locating a patient. The node is a WiFi access point tethered to an exterior command centre. Figure 1 depicts the CANES network configuration.

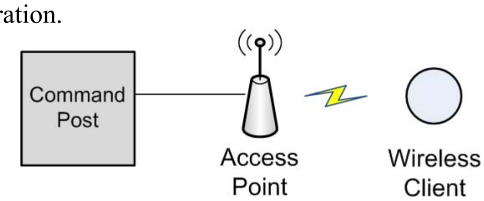

Figure 1 - Proposed network configuration.

II. Technical Approach

A functioning CANES consists a trained USAR dog, the CRDS—capable of detecting sustained barking to release a canine-carried package, and the carried package, consisting of a battery powered wireless access point connected to a light tether, encased in a custom designed container.

In rubble a tether can easily be snagged or tangled causing it to break or impede the dog from continuing to search. For these reasons, the tether is deployed from the dog. This deployment method presents an optimization challenge as the length of the tether dictates the size of the area that a dog can independently search. The challenge is to maximize the length of the tether while minimizing the size and weight of the overall package carried by the dog.

In our proof of concept system, we utilize a modified Category-5 (CAT-5) Ethernet cable as the tether. We modify the cable by stripping the shielding and reducing four twisted pair wires to two. This significantly reduces the size and weight of the cable.

We have designed and constructed a custom container to act as a magazine for the deploying tether. The size and shape of the container is dictated by the need to fit it under a dog while avoiding hindering the dog`s ability to search. Most tethers deployed by robots rely on some form of spool which unwinds as the robot progresses. Due to the mechanical complexity, size and shape restrictions imposed by the reality of dogs, we have opted to eliminate the spool. Instead, a container was designed to have a similar size and shape as other packages that we have successfully deployed and worked well with the CRDS. Figure 2 below illustrates the shape and dimension of the container which is capable of containing the 50-meter tether when correctly wound in in a layered figure-eight pattern.

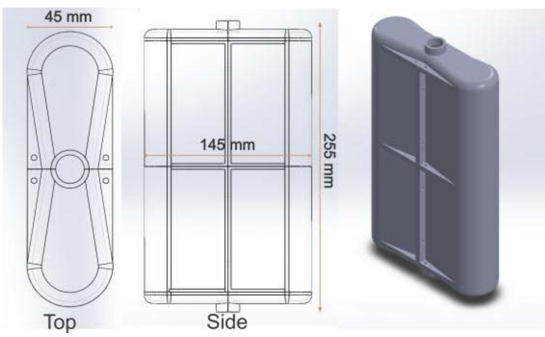

Figure 2 – Custom made tether container.

Although the bulk of the package carried by the dog is the tether container, a small WiFi router and a 7.4V, 800mAh Lithium Polymer battery pack is also included. The combined dimension of the router and battery pack is 120x75x25mm.

III. Initial Experiments and Results

Before we field test our system in rubble with search dogs, we have completed two sets of experiments in a controlled environment. One set of experiments tested the robustness of the tether deployment. The other test was an end-to-end verification of the transmission and throughput of two-way audio and video services.

In our tether deployment test, a human carried the tether running down a long hallway which made two 90-degree turns. While this human test did not match the top speed of a dog, it arguably matched the speed of a typical searching dog in relatively open space. Five trials were completed. In four out of the five trials, 100% of the tether was successfully deployed. In one trial 49m was deployed. The last meter was tangled inside the container. These tests give us confidence that our deployment mechanism will work reliably.

To test network throughput, we used an Internet-enabled laptop acting as a command post. A WiFi enabled smartphone acted as the wireless client delivered to the non-existent patient. The phone was intended to communicate through our deployed access point so that video and audio communication could be established.

The system was tested using two popular mobile applications, Google Talk and Apple FaceTime. It was confirmed that two-way audio and video communication could be established with acceptable fidelity using both of these applications under the proposed network configuration. It was also found that FaceTime was able to produce a more reliable image stream with higher frame rates when compared to Google Talk. This suggests that our network could handle the traffic, and that performance was largely software-related.

IV. Discussion and Future Work

In this report we proposed a means of establishing WiFi connectivity in the interior of a structural collapse. A two-way audio and video link was successfully established using the proposed network architecture. It was also demonstrated that the tether deployment method suggested is adequate. Even though in one trial, the tether did not deploy fully, it was noted that this was due to a fault introduced inadvertently through the laborious manual rewinding of the tether. Indeed, our figure-eight method of winding the tether has shown promise.

Future experiments will be performed with actual canines in an analogue rubble pile at an Ontario Provincial Police facility. Additionally, we plan on continuing work on the tether and deployment method.

The short term goal is to be able to place a full 100m of tether on a dog. This represents the maximum length of an Ethernet cable permissible because of signal attenuation. We also intend to develop a method to automate the winding of the tether. This will speed up the process of reloading and improve consistency of deployment. To ensure the safety of the dog carrying the tether, we plan to incorporate a safety system where the wire magazine will be automatically dropped when the tether is near the end of its length.

Our long-term goal is to explore the use of other types of tethers such as fiber optic cable—potentially allowing us to significantly increase the length of the tether.

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