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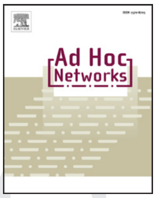

Location and mobility-aware routing for multimedia streaming in disaster telemedicine

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ABSTRACT

Disaster telemedicine leverages communications networks to provide remote diagnosis of injured persons in areas affected by disasters such as earthquakes. However, telemedicine relies heavily on infrastructure, and in a disaster scenario there is no guarantee that such infrastructure will be intact. In an ad-hoc network, devices form a network amongst themselves and forward packets for each other without infrastructure. Ad-hoc networks could be deployed in a disaster scenario to enable communications between responders and base camp to provide telemedicine services. However, most ad-hoc routing protocols cannot meet the necessary standards for streaming multimedia because they do not attempt to manage Quality of Service (QoS). Node mobility adds an additional layer of complexity leading to potentially detrimental effects on QoS. Geographic routing protocols use physical locations to make routing decisions and are typically lightweight, distributed, and require only local network knowledge. They are thus less susceptible to the effects of mobility, but are not impervious. Location-prediction can be used to enhance geographic routing, and counter the negative effects of mobility, but this has received relatively little attention. Machine Learning algorithms have been deployed for predicting locations in infrastructure networks with some success, but such algorithms require modifications for us in ad-hoc networks. This paper outlines the use of an Artificial Neural Network (NN) to perform location-prediction in an ad-hoc network.

1. Introduction

Millions of people are affected every year by both natural and manmade disasters. These lead not only to death and injury, but also the devastation of communities and sometimes entire nations. A common feature of such events is people trapped in an area, either those who physically cannot be moved or are cut-off from the outside world, and who require treatment. Even when such people can be reached it may not always be possible for the appropriate medical services to reach them on time. The explosion of the Internet and other communications networks, has seen the field of telemedicine go from a relatively obscure military system, to a disruptive service that millions of people around the world use to access medical care remotely. Today applications of telemedicine range from performing appointments over video conferencing to remote operation of medical equipment in surgery (Roine, Ohinmaa and Hailey, 2001). Telemedicine can therefore be of great benefit in providing services to people who are unable to access them directly, or allowing institutes to provide treatments they normally wouldn't be able to. In essence telemedicine seems perfect for use in disaster recovery scenarios. If doctors cannot attend an injured person then they can consult remotely, perform a diagnosis, provide instructions on treatment to others, and monitor the patients' condition. Telemedicine has been utilised during disasters, but its use so far is limited. After an earthquake in North Pakistan a field hospital was set up

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and webcams and computers used to communicate with remote specialists. Of the patients seen at the hospital a total of 28 patients were treated in some way via telemedicine [7]. Another example of telemedicine being utilised in the wake of a natural disaster is the University of Texas' existing telemedicine being damaged by a hurricane and a temporary telemedicine system being set up in its place [20]. However both of these systems, although being deployed in disaster recovery scenarios, made use of existing infrastructure albeit limited infrastructure in the case of the latter. Unfortunately communications infrastructure is not always available after a disaster. Cell towers and wired connections are all prone to damage. Even when some infrastructure is intact, it may not always be suitable for performing telemedicine. When you are treating a patient remotely a certain quality of video is required, and a damaged network may not always be able to deliver it.

Where communication between people in the disaster area or the vicinity of it is desired then ad-hoc networks could be a potential solution. Ad-hoc networks are an infrastructure-free model for networking in which devices wishing to communicate with each other form a network amongst themselves. Routing is then performed on a multi-hop basis where nodes forward a packet to each other until it reaches the destination. Thus all connected nodes are not only end-users, but also routers. Ad-hoc networks are considered to be distributed and decentralised as there is no infrastructure or servers. This can be seen as either an advantage or disadvantage, as the lack of control can lead to issues in ensuring all nodes behave correctly, but it can also prevent attackers from being able to destroy the network by targeting infrastructure. While an ad-hoc network cannot bridge a divide between the disaster area and the outside world, it can facilitate communication within it. Even if medical personnel are present they may not be able to attend directly to every injured person. If a first responder with some basic medical training could communicate with a doctor located at base-camp, the doctor could then relay instructions to the responder on how to handle the patient. Where some infrastructure is intact this could be incorporated into the network to allow devices who are able to connect to the ad-hoc network to access the outside world via it. The traditional ad-hoc model does not make any provision for this, but a sub-type the Hybrid Wireless Mesh (HWM) does. HWMs are similar to ad-hoc networks in that devices form a multi-hop network, but where they differ is their ability to incorporate infrastructure that can then be accessed through the multi-hop network by devices. In a disaster recovery scenario this would allow devices able to connect to the Internet to share their connection with other devices in the network. A significant problem limiting the use of ad-hoc networks for disaster telemedicine is QoS. To provide a suitable streaming service, strict levels of packet loss, delay, and jitter must be maintained. Ad-hoc network protocols are typically best effort, with the primary aim being to forward every packet to the destination. As such, ad-hoc networking protocols do not typically mechanisms such as classification and resource reservation found in infrastructure networks. As ad-hoc networks are not centrally managed implementing such policies is fraught with a number of organisational difficulties. Similarly, another technique used to manage QoS in infrastructure networks is inappropriate; overprovisioning, whereby significantly more capacity than is typically required is installed to provide redundancy. That is not to say that managing QoS and achieving standards suitable for streaming media in ad-hoc networks is impossible. However existing paradigms developed for infrastructure networks may be inappropriate, and thus new techniques must be devised.

Such approaches must overcome not only the challenge of decentralisation, but also other factors that make ad-hoc networks unique. One such factor is the potential for dynamic behaviour. While individual devices in an infrastructure network may fail, it is highly unlikely that such devices will be removed at random, and there will probably be some form of contingency measure. In an ad-hoc network nodes may leave or join at any point. This can have a disastrous effect, as the loss of one node can leave a node without a path, resulting in potentially wasted transmissions and the need to find another path. This problem is compounded in instances where mobility is permissible. Such networks are typically referred to as Mobile Ad-hoc Networks (MANETs). In contrast to static ad-hoc networks, MANETs are significantly more dynamic as node mobility can have a huge effect on connectivity. Even where a user does not wish to leave the network, if they move outside the range of another node the connection is lost. If ad-hoc networks are deployed in disaster recovery scenarios then it is likely they will take the form of a MANET. Even if the users of the stream remain static, there is no guarantee that the users of the other device that comprise the network connecting them will remain immobile. Thus mobility is liable to play a significant factor in the performance of any disaster recovery ad-hoc network.

If end-user applications are able to make use of a device's location and mobility data then it is logical to consider the possibility of using such information at the network-layer. Geographic routing covers a broad range of protocols that make use of such information varying extents. Geographic routing originates from a technical paper published by (Finn, 1987) that suggest the use of physical location in forwarding decisions. In its most basic form, greedy geographic forwarding, geographic routing forwards packets to neighbours based on their proximity to the destination. In addition to making use of physical locations, greedy routing is also lightweight as nodes do not store routing tables or topology. Instead nodes maintain a list of directly connected neighbours and perform forwarding on per-hop basis, selecting the neighbour closest to the destination and dropping the packet if no neighbour closer to the destination than the node itself can be found. This is done so as to avoid the possibility of routing loops where a packet travels backwards. Other approaches to geographic routing include face routing based on the Compass II protocol (Kranakis, 1999) where nodes traverse a planar graph and which theoretically guarantees delivery, but is considerably less efficient than greedy routing, as well as hybrid greedy—face protocols that combine the two approaches such as Greedy Perimeter Stateless Routing (GPSR) [9]. Geographic (or location-aware) protocols can also utilise location information to optimise specific criteria, such as in [17] where location is used to compute the connection time between two nodes, and [16] where mobility serves as an indicator of delay and jitter. These two protocols are interesting applications of how physical locations can

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