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Tracking user-movement in opportunistic networks to support distributed query-response during disaster management

Somprakash Bandyopadhyay[a]*, Apratim Mukherjee[b]

[a] *Social Informatics Research Group, Indian Institute of Management Calcutta, Kolkata 700104, India*
[b] *Department of Computer Science & Engineering, Michigan State University, MI 48824, USA*

Abstract

Effective communication amongst diverse rescue and relief workers is a primary requirement in any disaster management. Since pre-existing communication infrastructure may not be available, the Opportunistic Network framework provides a potential platform for information communication, where individual smart-phones of rescue and relief workers (the *nodes*) spread across an environment form a disjoint, peer-to-peer network. Here, a source node communicates with a destination node following hop-by-hop, store-wait-forward cycle, since an end-to-end route connecting them never exists. Also, due to mobility and disconnectedness, nodes have scarce or no knowledge about the network topology. However, in the context of disaster management, in order to evaluate the situation, rescue and relief workers often need to generate different field-related queries and the response to those queries must come from other workers in the field. Since source node (generating the query) is not aware of the location of destination node (answering the query) and all nodes are mobile, it is difficult to implement a query-response mechanism. This paper proposes and evaluates a distributed query-response mechanism that enables any node to track approximate location of other rescue and relief workers, which is turn helps to handle query-response operations.

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1. Introduction

In order to support disaster rescue and recovery efforts after any disaster, effective communication amongst the diverse rescue workers, as well as providing connectivity to survivors is a primary requirement. Police, Fire Departments, Public Health, Civil Defence and other organizations including local volunteers / field workers have to react not only efficiently and individually, but also in a coordinated manner. This results in the need for both intra and inter-organization information-exchange at several stages. However, disasters, whether natural or man-made, have severe impact on communication infrastructure. Services that are relied on for everyday communications (e.g., cell phone / internet connectivity) immediately become non-functional in emergency situations due to the failure of the supporting infrastructure through both system damage and system overuse [1].

In contrast to the vulnerable fixed network infrastructure, it is very likely that battery-powered wireless personal mobile communication devices (PDA, cell-phones) will survive disasters. Additionally, even more mobile devices will be brought to the scene by rescue workers, volunteers, and local authorities. Currently, those devices have powerful processors and high storage capacity with GPS and multi-radio interfaces (Cellular, Wi-Fi, Bluetooth). Such devices are, therefore, promising candidates to contribute in forming ad hoc wireless network structure to support disaster communication.

However, end-to-end connectivity can never be assumed in this kind of scenario and long disconnections and network partitions are the rule. Thus, in this context, Opportunistic Network framework [2,3] provides a potential platform for information communication. In opportunistic networks, the devices (PDA, cell phones) spread across the environment form the

* Corresponding author. Tel.: +91-33-24678300; Fax: +91-33-24678307.
E-mail address: somprakashb@gmail.com

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network. In this type of networks, the mobility of devices is an opportunity for communication rather than a challenge. Mobile nodes communicate with each other even if an end-to-end route connecting them never exists. Any possible node can opportunistically be used as the next hop, if it is likely to bring the message closer to the final destination(s).

In Opportunistic Networks, it is usually assumed that nodes have scarce or no knowledge about the physical network topology. However, in our context of application, it is important to track the location of mobile rescue workers and other agencies so that effective intra- and inter-organizational communication can be handled. In general, in this scenario, X may want to send a query to Y and like to get a response from Y, when (i) X and Y are not connected through network link(s), (ii) both X and Y are mobile, and (iii) message from X to Y will not travel instantaneously, but will travel opportunistically (following hop-by-hop, store-wait-forward cycle) which implies there may be significant delay in message communication from X to Y and vice versa.

This paper addresses a distributed location tacking mechanism to handle query-response process in an effective manner. In other words, the proposed mechanism would help a node know the approximate location-related information of other nodes in the system. The degree of accuracy of this information would depend on the inter-node distance and connectivity pattern of the opportunistic network. Once the approximate location information of destination node is known to the source node, query-response mechanism can be implemented using Geographic Routing [4].

The mechanism proposed in this paper is primarily based on a mobile multi-agent based framework. Mobile agents are an effective paradigm for distributed applications, and are particularly attractive in a dynamic network environment involving partially connected computing elements. Intensive research on the "Insect-like Agent Systems" has been done over the last few years. Of particular interest is a technique for indirect inter-agent communication, called stigmergy, in which agents leave information in the cache (which other agent can use) of the nodes they have visited. Stigmergy serves as a robust mechanism for information sharing [5].

We propose two types of agents: ***satellite agent*** and ***query agent***. Each node n_i has a dedicated ***satellite agent*** S_i. Task of S_i is to help exchanging information between its host node n_i and each of the neighboring nodes of n_i. To do this, the satellite agent S_i periodically hops from n_i to one of its neighbours with all location-related information as perceived by n_i. The neighbouring node has a different perception regarding location-related information of other nodes. S_i and the neighbouring node mutually exchange this information, forms a "consensus view" regarding the location related information of other nodes and Si then comes back to the host node n_i with this "consensus view". This would then change the perception of n_i about location-related information of other nodes. In the next time-slots, S_i visits other neighbouring node of n_i and the process is repeated. This mechanism is designed to mimic the real-life scenario in the context of disaster management. When a relief worker arrives at the field, s/he has no knowledge about the whereabouts of other workers. However, s/he exchange information with his/her neighbors one by one to get some idea (although imperfect) about others. Since no other communication mechanism is available, information assimilation by an individual can only be done using nearest neighbor interaction principle and exchange of information always takes place at a local level. Since nodes are mobile, information stability would never happen; but in the process, nodes will have approximate location information about other nodes.

Second type of agent is ***query agent*** that starts from the source node (query generator) with the query and approximate location information of the destination node, navigates autonomously hop by hop to reach the destination (response generator), collects the response and returns back to the source node. As it approaches closer to destination node, it will have more accurate location information about the destination node and accordingly it modifies its navigation.

2. Related Works

Opportunistic Networks and opportunistic computing has become a major research area in the recent past. Designing routing and forwarding schemes is one of the main challenges in this environment. However, forwarding and routing protocols are merged in this context, because routes are actually built while messages are forwarded [2]. The forwarding scheme has been primarily referred as "store, carry, and forward". Each intermediate node evaluates the suitability of encountered nodes to be a good next hop towards the destination. Another form of routing technique exploits some form of flooding. The heuristic behind this policy is that when there is no knowledge about a possible path towards the destination or of an appropriate next-hop node, a message should be disseminated as widely as possible. The most representative protocol of this type is Epidemic Routing [6] and some optimizations of the same [e.g.,7]

However, flooding-based approach generates multiple copies of the same message. In Forwarding-based approach, though there is only one single custodian for each message, it may suffer long delays and low delivery ratios. Several schemes have been proposed considering mobility pattern / context information into account. The Haggle Project [8] has developed mechanisms for measuring and modelling pair-wise contacts between users and devices by means of two parameters: contact durations and inter-contact times. The statistical properties of these parameters are used to drive the design of forwarding policies. Probabilistic Routing scheme [9] calculates the delivery predictability from a node to a particular destination node based on the observed contact history, and it forwards a message to its neighbouring node if and only if that neighbour node has a higher delivery predictability value. Leguay et al. [10] have taken the mobility pattern into account, i.e., a message is forwarded to a neighbour node if and only if the neighbour node has a mobility pattern more similar to the destination. However, in many application scenarios (such as ours), mobility patterns are largely unpredictable. Also, there are some efforts to use opportunistic networks in the context of disaster management [11,12].

Nevertheless, a successful information forwarding scheme in opportunistic networks not only needs to consider delay performance, but it must also consider the nature of its application. Effective schemes dealing with different application requirements remain challenging and desirable. As indicated earlier, in our context of application, it is important to track the