Dynamic Topology and Communication Control for Highly Dynamic Wireless Mesh Networks

A Public Safety Network Point of View

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Abstract — **Dynamic environments, such as wireless mesh networks, require flexible and self-adaptive mechanisms to control topology and medium access. Conventional algorithms, developed for quite stable networks, either do not work properly in this new environment or perform poorly. This work intends to study and develop dynamic and self-adaptive strategies to control the topology and the medium access for wireless mesh environments. Wireless Public Safety Networks, are an extreme case where dynamic and self-adaptive controls become important. Even though the proposed schema intends to be general and adapted to any wireless mesh network, we believe that we can benefit if we succeed in applying our method to highly dynamic and unpredictable networks, as it is the case of public safety networks (PSNs). The early evaluations of the technique proposed here show the method is able to successfully handle the different requirements and variation of PSNs.**

Keywords – dynamic topology control; auto organization; mesh networks; connection cost; public safety networks

I. Introduction

The deployment and management of nodes for wireless mesh networks (WMNs) is a fundamental and challenging problem. Well defined and maintained network structure is an indispensable step to enable the creation of efficient higher layer algorithms [2]. For this reason topology control becomes a fundamental functionality to enhance scalability and capacity for large-scale wireless ad hoc networks [3].

The problem becomes even more challenging in the public safety networks context, since the requirements and way of working of these networks vary significantly for different disaster scenarios. For example, the number of nodes, end users, mobility pattern, deployment environment and communication requirements for a forest fire fight network differ greatly from the ones of an earthquake relief effort network. Developing specific algorithms and equipments adapted to each one of the situations is possible, but not desirable, since the vehicles and people involved in different disaster sites are normally the same. Multiple algorithms and equipments would not only be more expensive, but also be harder to manage and control. This goes exactly against the more basic needs of public safety networks. The last thing one should consider in a disaster relief effort is the best algorithms and equipments to use. People must to focus in saving lives, any distraction may have fatal consequences. In contrast to what happens with regular public access networks, the main concerns for public safety networks are rapid deployment and survivability [1].

The next section clarifies the points addressed by this research proposal and highlights its expected contributions. Section 3 introduces the proposed solution and some early results. Section 4 presents the conclusions and future directions for this work.

II. The Problems Addressed by This Research

Our research intend to evaluate and develop methods for dynamic control of the topology, admission control and medium access control for wireless mesh networks. Regular methods to address these problems, normally consider one specific network that is either static or presents low change rates. This work, on the other hand, targets dynamic networks and primes for algorithms that enable networks to self adapt to new conditions and requirements on the fly. For example, the same framework should be able to shape the network to the forest fire fight and earthquake relief effort sites, obeying each one specific requirements.

We understand that not only the topology but also the traffic should self adapt to different network requirements. We go even further, we believe it should be possible, for different parts of the network, to have different requirements and still be part of the same network.

A. *The research questions we are trying to answer*

- Is it possible to use the same framework to shape networks with radically different requirements?
- Given a generic network list of requirements is it possible to shape the topology in a specific way?
- Is it feasible to change the topology of an already established topology, if the case, whenever the requirements for that network change?
- Is it possible to have, in the same network, parts with different requirements and obeying different regimes?
- Is there a simple way of doing it? At least one way that does not require any special purpose equipment or extremely complex and heavy algorithms.
- Is it possible to achieve all these goals with minimum interference from outside of the network?

B. *The Expected Contributions*

- Techniques to enable highly dynamic networks to control their topology and medium access
- Simple and efficient self-adaptation methods to network with heterogeneous characteristics

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III. THE PROPOSED SOLUTION

This work is still in progress but we already have some insightful and promising results. Indeed, our results point that the answer for all the previous stated questions is yes. To validate the proposed solution and the assumptions we have made, we used the topology proposed by the CHORIST project [4]. This project is funded by the European Commission, and addresses Environmental Risk Management in relation to natural hazards and industrial accidents [4]. The backbone topology, depicted in Figure 1, is composed of Cluster Heads (CHs), Mesh Routers (MRs) and Relay Nodes (RNs). All the nodes' roles and clusters must be defined dynamically and based only on local information.

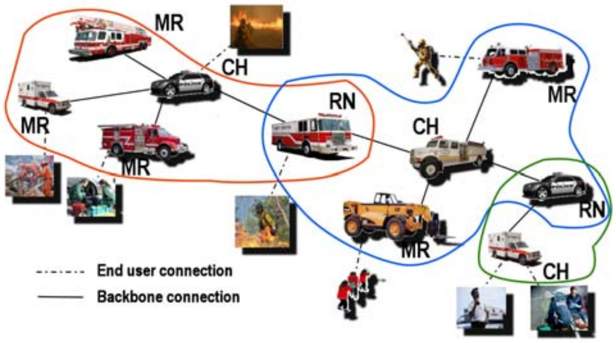

Figure 2 – CHORIST network description and components

We base our technique in the economy laws of supply and demand to dynamically organize the network. These economic concepts can perfectly map the main requirements of a topology management algorithm (stability, load balancing and connection demand). The first law of supply and demand states that when demand is greater than supply, prices rise and when supply is greater than demand, prices fall. These forces depend on how great the difference between supply and demand is. The second law of supply and demand, then, states that the greater the difference between supply and demand, the greater are the forces on prices. The third law states that prices tend to the equilibrium point, where supply is equal to demand [5]. These same concepts are used to control the network behavior. We define a cost function to enable the network to self-organize and manage its topology and admission control.

The proposed algorithm, relying supply and demand laws and working with local information, is able not only to dynamically adapt to different requirements, but also to create homogeneous clusters. To validate the proposal, we defined a cost function, and simulated several different costs and payoffs for the different network components. Each one of the evaluated configurations has a particular objective such as target numbers of CHs and MRs, or maximum cluster sizes. The graphs of Figure 2 show the occurrence of CHs over the simulated area for different configurations. We can observe that the number and distribution of the CHs changes for each scenario. The laws of supply and demand proved to be a flexible and distributed way to perform network admission control and topology management.

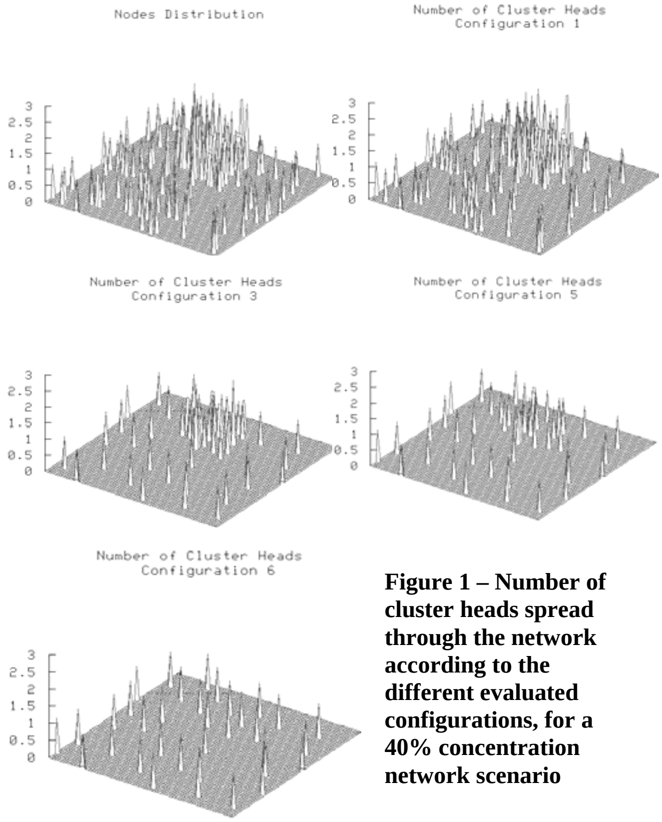

Figure 1 – Number of cluster heads spread through the network according to the different evaluated configurations, for a 40% concentration network scenario

IV. CONCLUSIONS AND FUTURE WORKS

The results show that by handling only local information and without the complete final network configuration, the proposed method manages to successfully organize the nodes in the desired topology, respecting the desired final network behavior. The cost function, which controls the protocol behavior, can be as simple or as complex as one needs it. For the results presented here we choose to focus on the number of CH nodes. However, other factors could be taken into account, e.g. perceived quality of signal, number of blocked nodes and mobility pattern. The important point is that the cost function calculation is a flexible way to control the network connections and the topology behavior. This flexibility is an interesting asset, mainly for public safety networks, since different disaster sites could have different network requirements and the network operation can be shaped as desired.

The next steps are the application of such technique to the medium access control problem and implementing the technique, to evaluate its behavior in a real environment.

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