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Onto scalable wireless ad hoc networks: Adaptive and location-aware clustering

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ABSTRACT

Clustering is a widely used solution to provide routing scalability in wireless ad hoc networks. In the literature, clustering schemes feature different characteristics and purposes, however few schemes are context-aware. This work proposes a new solution called Distributed and Location-aware Clustering (DiLoC), a clustering scheme designed to operate in indoor environments, providing mechanisms to gather context location information in order to ease the maintenance of clusters, thus resulting in a stabler network topology in order to provide a scalable network topology for an efficient routing. DiLoC considers three distinct approaches, regarding the characteristics of the deployment environment, aiming to cover infrastructure-less, infrastructure and hybrid network scenarios. DiLoC was evaluated and compared with a similar clustering scheme, featuring the stability, amount of clustered nodes and network load. Included results demonstrate a scalable algorithm with a significant high stability.

1. Introduction

With the evolution of wireless technologies, there has been an increasingly wide utilization of mobile devices. Mobile networks have become particularly attractive in the recent years due to their flexibility at considerable low costs. Wireless is indeed one of the nominated communication technologies of the future, since it has the potential to allow the connection of all types of mobile devices.

Wireless ad hoc networks are autonomous systems, capable of self deployment and maintenance, not dependent from existing network infrastructures for their operation. As a result, the topology of such networks is very dynamic, especially due to the unpredictable behavior of the nodes involved. In this context, numerous clustering schemes were developed, following different approaches and objectives, such as stability, low maintenance overhead or energy efficiency. Each one attempts to obtain the best efficiency by varying the characteristics of the system, like the usage of clusterheads and gateways, the maximum hop distance between nodes and the location awareness. However, there are very few clustering schemes which provide a fully distributed cluster structure with no clusterheads.

In recent years, a wide growth of wireless systems has been noticed. Wireless technologies are present in consumer applications, medical, industrial, public services, transports and much more. Therefore, there is a high demand for accurate positioning in wireless networks, either for indoor or outdoor environments. Concerning the nature of the application, different types of location are needed, which can be characterized as physical location, symbolic location, absolute location and relative location. Physical location is expressed in coordinates, identifying a point on a map. Symbolic location refers to a location in natural language, such as a coffee shop, and office. Absolute location uses a global shared database system, which references all located objects. Finally, relative location is usually based on the proximity of devices, e.g. known

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reference points, providing an environment-dependent location. The latest is the most common used paradigm in literature.

Currently, there are many wireless location technologies, such as Radio Frequency (RF) based (WLAN, Bluetooth, ZigBee, RFID), Infrared (IR), ultrasound, and GPS. However, each technology has its advantages and disadvantages, and environment scope. No single technology is applicable to all services and circumstances. Recent studies have deeply concentrated on developing indoor location systems, since GPS offers an good solution for outdoor environments.

In this work, a new clustering scheme is proposed, namely Distributed and Location-aware Clustering (DiLoC), aiming to further improve the stability of the cluster structure.

The remaining of this document is organized as follows. Section 2 discusses the related work, covering some of most significant clustering schemes and location sensing solutions. Section 3 describes the DiLoC clustering scheme. Section 4 performs a comparison evaluation of DiLoC and, finally, Section 5 concludes the article.

2. Related work

This section conducts a study of some important clustering schemes in literature, followed by the main location sensing systems. This overview aims to analyze the different employed characteristics and mechanisms in order to provide a better understanding of the proposed solution.

2.1. Clustering

Clustering algorithms can be classified according to different characteristics and objectives [1]. One of the common features in clustering schemes is the utilization of clusterheads (CH) and most of the proposed schemes rely on centralized nodes to manage the clusters structure. The utilization of gateway (GW) nodes is also another important characteristic that is present in the majority of clustering schemes. Other properties of clustering schemes concern the single-hop or multi-hop environments, the multi-homing (MH) support, embedded routing capabilities and location awareness. Combining the possible characteristics, each proposed clustering scheme attempts to accomplish a specific objective.

The Stable Clustering Algorithm (SCA) [2] aims at supporting large Mobile Ad Hoc Networks (MANETs) containing nodes moving at high speeds by reducing re-clustering operations and stabilizing the network. To meet these requirements, the algorithm is based on the quick adaptation to the changes of the network topology and reduction of clusterhead reelections. In order to avoid a high frequency of clusterheads reelection, the algorithm initially chooses the nodes that best meet some required metrics such as energy, mobility, connectivity and communication range. The Enhanced Sectorized Clustering Scheme based on transmission range (ESCS) [3] also pays attention to the connectivity and energy of nodes. Clusterhead nodes are chosen according to the energy amount of nodes, selection those with potentially longer lifetime. For this election, the connectivity of nodes is also accounted by measuring the node density, i.e. the amount of nodes within a sector. Results feature the network lifetime, showing that this schema is superior, particularly for scenarios with a larger amount of nodes. The Signal Energy Efficient Clustering (SEEC) [4] is also based on the energy level of nodes and signal strength. Once more, the these metric are used particularly in the election of clusterheads. SEEC constantly monitor the energy levels of clusterheads and preventively replace them before energy is depleted.

The Stability-based Multi-hop Clustering Protocol (SMCP) [5] also builds the cluster structure according to the node connectivity quality. Moreover, this scheme introduces a new methodology (clustercast mechanism) with the purpose of limiting the broadcast of less significant control messages. The K-hop Clustering Protocol (KhCP) [6] protocol is specifically designed to cluster dense MANETs, as it delimits the cluster formation at a specified *k*-hop distance. In this protocol, clusters are formed on a circle basis, whereas the clusterhead, at the start point, is the center of the circle. A weight-based clustering scheme, named Distributed Weighted Clustering Algorithm (DWCA), was proposed with the objective to extend the lifetime of the network, by creating a distributed clustering structure [7]. The election of clusterheads is based on the weight value of nodes, which is calculated according to their number of neighbors, speed and energy. The Enhanced Performance Clustering Algorithm (EPCA) [8] is also a weight based clustering solution. Once more, the weight parameters are only taken into account for the selection of the clusterhead.

The Connectivity-based Clustering Scheme (CCS) [9] has the purpose of improving the effectiveness, reliability and stability of MANETs. In contrast with most schemes, this solution ignores mobility and energy parameters, focusing only in the cluster organization to achieve its objectives. In order to provide effectiveness and low maintenance, it utilizes a technique of maintaining clusterheads separated by a significant hop distance. Therefore, the probability that two clusterheads come into each other's transmission range is reduced, decreasing the number of re-clustering operations. Concerning the reliability objective, an intra-connection degree is used to measure the connection quality between a node and the possible clusters that it can join. The Energy Efficient Mobility-sensitive Clustering (EEMC) [10] presents a solution for energy balancing. The main objective of this scheme is to extend the lifetime of the network, by distributing the load amongst nodes and also regarding their mobility. The Trust-related and Energy-concerned Distributed MANET Clustering (TEDMC) [11] is also a scheme driven by energy concerns. TEDMC considers that the most important nodes are the clusterheads, and therefore it elects them according to their trust level and residual energy. In order to keep information about the trust level of nodes, this algorithm maintains and periodically exchanges a reputation rank table, which contains a reputation value and the unique identification of the last node to assign the value in question.