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A survey on clustering techniques for cooperative wireless networks

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ABSTRACT

Clustering became relevant in the past as a solution for the scalability problems of ad hoc networking, but, the unsuccessful application of ad hoc solutions to real scenarios, such as the projects SURAN and PRNet, decreased the interest of research community on ad hoc communications, and subsequently, on clustering algorithms. Recently, however, clustering techniques have gained renewed interest due to the emergence of cooperative communications for cellular networking. Clustering is envisaged, in this scenario, as a technique to team up nodes to support efficient data aggregation for energy saving, scalability and privacy among other benefits. Moreover, research on 5G networks also envisages a connected society, where everything and everyone will be connected under the umbrella of Internet of Everything (IoE). This novel communication paradigm has fostered new research on clustering, which has yielded novel and more advanced algorithms and applications. This article surveys the State-of-the-Art in clustering techniques and provides detailed descriptions of the basics of clustering and the latest novel ideas. Open issues, technical challenges and directions for future research are also outlined.

1. Introduction

Clustering, in telecommunication systems, appeared in the framework of ad hoc networking, which was proposed decades ago as a promising solution for infrastructure deprived networks, such as military battlefield communications, emergency communication black-outs or to deploy fit for purpose wireless networks [1]. The idea of setting a network, on-demand, without implementing access points or base stations, was very appealing from both the utility and economic perspective. In ad hoc networking, the nodes communicate among themselves by transmitting and relaying the packets from source to destination, without a common hub that routes the packets or organizes the communication flow. This paradigm, however, requires complex routing mechanisms to optimize the route path selection and ensure a satisfactory packet delivery ratio. This was indeed the bottleneck of ad hoc networking, since the unpredictable nature of this scenario, where nodes show up and vanish continuously, requires a continuous update of the routing information. This information can grow significantly in big networks, due to the countless route paths that routing algorithms must evaluate. Clustering was suggested in this framework to reduce the routing complexity and provide scalability. The strategy of clustering is teaming up nodes in virtual groups, with one leader per group, such that routing techniques consider these groups as sole entities, hence reducing the number of network sources, destinations and possible paths considerably, hence increasing its stability.

The research interest in clustering techniques went side by side with the concern of ad hoc networking, very prolific during two decades, producing research efforts in a variety of scenarios and technologies such as mobile wireless networks and sensor networks. This interest however has been gradually declining due to the absence of implementation of ad hoc solutions in real scenarios. With the sole exception of wireless sensor networks, ad hoc networking has been considered a liability problem, and the main projects on ad hoc solutions for military and emergency situations have failed [2,3]. Clustering, originally designed for ad hoc networking, lost some relevance for research community. However, the emergence of more advanced wireless devices such as smartphones, wearable technology and vehicular networks, provided with higher processing capabilities and multi-standard wireless interfaces, has catered a new scenario for clustering in the framework of cellular networks and cooperative communications. In this scenario, cooperation provides many benefits and only one requirement. The benefits include energy efficiency, scalability, efficient location services, social networking and privacy preserving among others. The requirement is an efficient technique to establish cooperative groups of nodes, i.e. clusters.

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