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Survey Paper

Monitoring in mobile ad hoc networks: A survey

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ABSTRACT

The growing use of small wireless devices is making mobile ad hoc networks indispensable as an effective solution for ubiquitous computing and internet of things. Moreover, these networks are considered as a communication solution for emergency or disaster situations. However, to be usable at this scale, mobile ad hoc networks need to be monitored if not totally at least partially. Monitoring is a network management function that can be achieved inside the network without any external intervention. The purpose of monitoring in such networks is to collect information such as the functional states of the participating nodes and the operational states of the available routes and to report this information to all participating nodes or to some of them according to the network application. This paper outlines the challenges of monitoring over mobile ad hoc networks. We discuss monitoring issues and provide a comprehensive overview of existing monitoring approaches. We present a classification of these approaches based on mobile ad hoc network characteristics, their deployment issues and the way the network is organized. For each approach, we present a brief overview, then we describe the architecture and the proposed protocols; we discuss their advantages and limitations; and we compare the approaches based on common criteria such as message overhead and distribution.

1. Introduction

Wireless technology is invading our daily life by the increasing use of portable computers and smartphones. These small devices can be connected everywhere and provide the ability to create quickly a network in unexpected or urgent situations without any extra cost, additional installation or infrastructure [1]. These flexible networks are called Mobile Ad hoc NETworks or simply MANETs. MANETs are also called hop by hop networks as nodes cooperate to create and maintain the network by acting as routers that relay communication packets hop by hop. This hop by hop relaying allow distant nodes to communicate with each other.

MANETs' devices are not mainly powered and relay on batteries. Consequently, energy savings in these networks is a key issue in maintaining the network services. A node that depletes its energy is no longer usable in the common collaborative effort that feeds the network. MANETs have also a dynamic topology mainly because nodes are mobile but this dynamism can also be the consequence of variation of signal quality, a depletion of the energy of some nodes that leave the network or because of new nodes that join the network. A monitoring activity in these networks not only helps the participating nodes to have a view on the state of the network, its size and how it is used but it also provides network designers and researchers with practical information that can be we used to improve protocols and systems through the analysis of monitoring data [2,3].

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Monitoring is one of the main functions that are performed as part of network management. Network management refers to the activities, methods, procedures, and tools that concern the operation, administration, and maintenance of networked systems [4]. MANETs are commonly assumed to be entirely self-managing and usually no human intervention is required which is incompatible with the management operations and functions. Nevertheless, several management solutions are proposed for MANETs [5] even if they do not include all the functionalities we find in a global management solution intended for a structure-based network. Some applications of MANETs such as emergency or disaster situations or military networks tolerate external management and monitoring to optimize the network's parameters [6]. We focus here on monitoring as a fundamental and minimal management function whatever is the application of the MANET. In fact, monitoring is the management function that can be achieved inside a MANET with no outside intervention. The aim of this paper is to survey the fundamental issues and proposed solutions for monitoring in mobile ad hoc networks. It is an exhaustive survey that analyzes all monitoring approaches even those that are part of a more complex management solution. An earlier survey by Badonnel et al. [5] focuses on the main management paradigms, including monitoring, and their underlying architectures in MANETs. It presents an overview of the management solutions proposed between 1999 and 2006 and classifies them according to the organization of the network. It also discusses their use according to the management purposes such as: fault, security and configuration. In [7], the authors provide an overview of five management approaches that were proposed between 1999 and 2009. They classify these approaches according to the protocol used to collect monitoring information. They raise their theoretical and practical limitations such as high message overhead and single point of failures.

The reminder of this paper is organized as follows: Section 2 is devoted to the basic concepts of mobile ad hoc network monitoring and its challenges. Section 3 gives the main criteria we use to describe monitoring approaches. In Section 4, we review and analyze existing monitoring approaches. In Section 5, we discuss the presented approaches and compare them. Section 6 brings our remarks concluding the paper.

2. Monitoring challenges in MANETS

Monitoring is an activity of observation which consists in collecting functional data from the nodes and the links of the network [5,8,9]. Examples of collected data are energy level, storage capacity, band-width, etc. These data may be analyzed to detect anomalies such as failures, intrusions and disconnections and to construct some global view of the network. The collected data or the obtained results after analysis may then be disseminated throughout the network or simply stored on some of the nodes for further use according to the network applications.

Mobile ad hoc networks monitoring faces several challenging issues. Comprehensive descriptions of these issues can be found in [10,11,3,12,5]. We review here the most important ones and point-out other problems that arise due to the recent developments in mobile and wireless technologies as well as the strong demand on quality of service from applications. Fig. 1 summarizes these issues according to four categories:

1. Survivability issues [11]: Survivability is the ability of a monitoring approach to fulfill its mission in presence of attacks and failures. Survivability issues are mainly:
   - Robustness [10,5]: when a node, which is responsible of some monitoring tasks, fails, moves or leaves the network, the monitoring activity should not stop. The monitoring solution must provide a fault-tolerant service.
   - Distribution of the storage load [5]: monitoring data maintained by nodes can be lost if these nodes fail or leave the network. So, monitoring approaches must avoid centralized storage solutions to ensure the availability of monitoring data to all the participating nodes.
   - Distribution of the control load [5]: monitoring tasks must be controlled and supervised. However, control and supervision should not be centralized into few nodes to ensure the continuity of the service.

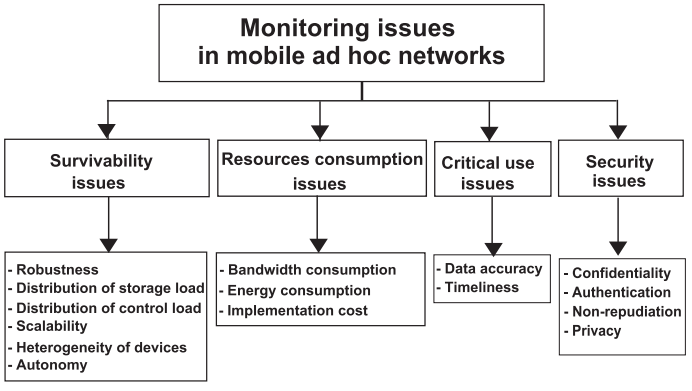

Fig. 1. Mobile ad hoc network monitoring challenges.