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A link-state QoS routing protocol based on link stability for Mobile Ad hoc Networks

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ABSTRACT

In this paper, we propose a new mechanism to establish stable and sustainable paths between all pairs of nodes in a Mobile Ad hoc Network. In this mechanism, we use a stability function as the main path selection criterion based on the calculation of the mobility degree of a node relative to its neighbor. We applied this mechanism on the OLSR protocol (Optimized Link State Routing Protocol) to elect stable and sustainable MPR (Multipoint relays) nodes and topology. This mechanism significantly minimizes the recalculation of MPR and the routing tables recalculation process. Moreover, it guarantees other QoS (Quality of Service) metrics such as the packet loss and the response time. The simulation results show the effectiveness of our mechanism and encourage further investigations to extend it in order to guarantee other QoS requirements.

1. Introduction

Mobile Ad hoc Networks (MANETs) are a class of infrastructure less networks, which are formed by a number of autonomous wireless and mobile nodes (Corson and Macker, 1999). The inherent characteristics of such networks make the support of multimedia applications very challenging. In fact, the nodes' mobility and the scarce resources directly impact the deliverance conditions of packets, which also depend on the selected paths' quality (Gangwar, 2012). The classical routing strategies, such as AODV (Ad hoc On-demand Distance Vector) (Perkins et al., 2003), DSR (Dynamic Source Routing) (Johnson et al., 2007) and OLSR (Clausen and Jacquet, 2003), mainly focus on minimizing the number of hops of the provided paths. This criterion is clearly inefficient to guarantee the services' quality. Indeed, minimizing the number of hops does not guarantee the quality of the selected links. Otherwise, these protocols select, by default, the farthest nodes to reach the destination with the minimum number of hops. In this way, many QoS-enabled routing protocols were proposed. Some of these protocols attempt to provide the best paths in terms of a selected metric (distance, signal power, etc) or a combination of metrics (example: speed and angle of movement of nodes) (Chlamtac et al., 2003). Some other approaches focus on resources' reservation (Chlamtac et al., 2003). In these two classes of protocols, the nodes mobility is not really considered. In fact, the nodes' mobility may clearly affect both the quality of the selected paths and their durability. Thus, the route selection process should also consider the link stability criterion (i.e. links' durability), which allows to maintain the characteristics of the selected paths (Zhu et al., 2006).

To address the stability of links, the routing decision is usually based on the signal strength or the distance between the nodes. Most of the existing protocols consider the signal strength/distance to guarantee the link stability during a certain period of time. However, these approaches lead to the selection of the nearest nodes which increase the hops' count. This may clearly degrade the QoS of the supported applications and affect the performance of the network (Lal et al., 2011).

Analyzing the existing protocols allows us to classify the earlier works focused on the routing protocol based on the link stability in two classes: based on the distance and based on the mobility of nodes. The major of these protocols assesses the link stability based on the geographical positions of the nodes, provided by the GPS (Global Positioning System), or proposes the complicated probabilistic methods to estimate the reliable link lifetime. The routing mechanism based on the link stability, which minimizes the frequent path disconnections and guaranties other QoS requirement such as the packet delivery ratio, constitutes the first motivation of this work. So, in this paper, we present a new probability-based mechanism enabling an accurate estimation of the links' stability. We consider the signal strength variation as a main indicator of the nodes' mobility. The use of such metric allows to effectively select the best paths in terms of stability. In opposition to the existing approaches, it allows, at the same

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time, to optimize the hops' number by selecting nodes based on their mobility and not on the signal strength or distance. Since the proposed technique mainly depends on periodically exchanged packets, we propose to apply it as an extension of a proactive protocol. The OLSR protocol is considered in this paper. Thus, we propose the modification of two mechanisms of the classical OLSR protocol: the MPR selection and the topology discovery.

The rest of the paper is organized as follows: Section 2 is about the related work. So, we select and summarize several studies on the same issue and we will classify them to statute our work. The proposed mechanism to estimate the link stability is detailed in Section 3 and we describe the integration of this mechanism into the OLSR protocol in Section 4. Section 5 analyses the performance of the proposed approach and we conclude our work in Section 6.

2. Related work

In this section, we present some routing protocols based on the link stability in wireless Ad hoc networks. First, we classify these protocols according to two metrics: the distance and the mobility of nodes. Distance-based protocols try to minimize the distance between a node and its successor in the established path. In the second class, protocols try to quantify and assess the links between nodes of the network based on their mobility. This class regroups two types of protocols: class of protocols based on the parameters of nodes' mobility (speed, direction of movement, coordinates of nodes, etc) and class of protocols based on the degree of mobility or the probability that the mobile node remains a neighbor of another node (probabilistic methods).

2.1. Distance based protocols

We present in this section an overview of works that summarizes the class of distance-based protocols. The distance between nodes is calculated generally using localization systems or based on the signal-power of messages exchanged between nodes. In Wang San et al. (2005), authors proposed the protocol SSOD (Signal Strength based On-Demand). This protocol installs paths according to the signal strength metric. After receiving several answer messages by the source, it selects the path that its minimum value of signal powers is the largest in comparison with the minimum values of the other paths. The path, that has the sum of the links' stability parameters greater than the sums of the other paths, will be elected as the most stable in the case of multiple paths. TBP-SE (Ticket-Based Probing with Stability Estimation) proposed in Zhu et al. (2006) is an amelioration of Ticket-Based Probing protocol (TBP) (Chen and Nahrstedt, 1999). This last, installs paths based on QoS requirements but without considering their stability and their durability. For this, the authors of TBP-SE have added to this protocol another metric for stable and durable paths selection. This metric of link stability, based on the distance between nodes, is calculated by the information provided by the GPS or the signal quality. In Alicia et al. (2006), the authors proposed an approach based on the signal power to evaluate the links' stability. For this, the authors propose two criteria: the first selects the path that has the minimum signal power greater than the minimum signal power of the other paths, and the second installs paths depending on the number of hops and checks the first metric. Nityananda Sarma and Sukumar Nandi have proposed a protocol based on the signal strength to estimate the stability of the link (Sarma and Nandi, 2006). The authors consider the link stability with other QoS metrics to obtain a QoS routing protocol based on the link stability. The path that has the largest product of links' stability values compared to the other paths will be elected as the most stable.

2.2. Protocols based on the mobility of nodes

Several protocols consider the mobility of nodes to estimate the stability value of links such as the direction of movement of nodes, their speed and their probability of remaining in the vicinity for a long period. Authors in Tarng et al. (2006) proposed a method to calculate the probability that a node receives a signal from its neighbor with a power higher than a predefined threshold. The information of mobility of nodes is received by the localization system (GPS). This protocol is similar to AODV in its phases of installation and maintenance of paths except the path selection metric which is based on the link stability instead of the number of hops. In Li et al. (2010), authors propose a protocol where the choice of the path is done based on two metrics: the residual energy and the mobility of nodes. For this, they have proposed a formula to calculate the weighted sum of the two metrics. The authors calculate the residual energy metric as the remaining energy of a node divided by the rate of the traffic that passes through this node. The second metric is calculated as the difference of the number of the node's neighbors in time T and time $T-\delta(T)$ divided by the number of its neighbors in time T. Authors of the protocol LSEA (Link Stability and Energy Aware) (Hamad et al., 2011) proposed some changes in the protocol AODV to address the path durability and the amount of residual energy constraints. These changes were made on the propagation of the RREQ (Route Request) packets especially for nodes that have a better satisfaction of both the constraints. To evaluate the link stability, they used the method proposed in Su et al. (2001) which is based on the GPS system. Another link stability based protocol is proposed in Lian et al. (2008) where the objective is to ensure, first, a sufficient bandwidth, and second, the delay, an acceptable jitter and a long lifetime of the selected paths. The lifetime of paths is calculated as a function of vectors of speeds and positions of the nodes received by the GPS system. Three schemes have been proposed in Al-Akaidi and Alchaita (2007) to establish paths toward the geographical direction of the destination node using the Localization System or the direction sensors. In the first scheme, the diffusion of the RREQ messages is intended only to nodes that are in the same direction as the destination node. In the second scheme, the zone propagation of the RREQ packets is divided into eight zones of 45° where the source node sends requests to one node in each zone. In the last scheme, the RREQ messages are sent only to the geographical direction of the destination node. Another protocol called SWOP (Stable Weight-based On-demand routing Protocol) (Wang et al., 2007) was proposed. This protocol uses three criteria to select a path: the expiration time of path, the number of errors and the number of hops. For this, a function that calculates the weighted sum of these three factors has been proposed. The synchronization of nodes and the parameters of motion are obtained by a localization system such as GPS. The expiration time of the link is calculated as a function of the speed, the angle of motion and the coordinates of the nodes. Authors in De Couto et al. (2005) proposed a well-known metric for electing the stable node by estimating the number of transmissions required to successfully send a packet over that link called: ETX (Expected Transmission Count). The ETX for a path is the sum of the ETX metrics for each link on this path. This metric is proposed to be incorporated into OLSRv2 (Rogge et al., 2010). LLMR (Learning automata-based Link stability Multicast Routing algorithm) is a new algorithm proposed in Akbari Torkestani and Meybodi (2011) and based on a stochastic Steiner tree algorithm for constructing the multicast route in Ad hoc networks. In this algorithm, a learning automata is proposed for solving the proxy Steiner tree problem, where the duration of a communication link is defined as the random weight of its corresponding graph edge. The duration of the communication