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Performance evaluation and simulations of routing protocols in ad hoc networks

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Abstract

A mobile ad hoc network (MANET) is a collection of wireless mobile nodes communicating with each other using multi-hop wireless links without any existing network infrastructure or centralized administration. In recent years, a variety of routing protocols targeted specifically at this environment have been developed and some performance simulations are made. However, the related works took the simulation model with a constant network size and a varying pause times or mobility velocities. And these works do not take into account the influence on the protocols when the mobile nodes' pause time is invariable but the network size is changing. On the contrary, This paper considers the problem from a different perspective, using the simulation model with a dynamic network size and an invariable pause time which should be zero under weakest case because a longer pause time of the node may be insignificant for mobile Ad hoc network with frequently and fast moving nodes. Furthermore, based on the QoS (delay, jitter, throughput, loss ratio), routing load and the connectivity (to our knowledge, we first use the jitter and the connectivity as the valued metrics in the simulation of wireless ad hoc network protocols), this paper systematically discuses the performance evaluation and comparison of four typical routing protocols of ad hoc networks with the different simulation model and metrics, and drew more complete and valuable conclusions.

Keywords: Performance evaluation; QoS; Ad hoc networks; Network simulation; Routing protocols

1. Introduction

In an ad hoc network, mobile nodes communicate with each other using multi-hop wireless links. Such networks find applicability in military environments, wherein a platoon of soldiers of fleet of ships may construct an ad hoc network in the region of their deployment, as well as in nonmilitary environments, such as classrooms and conferences room. Military network environments typically require quality-of-service (QoS) for their mission critical applications. In nonmilitary environments, multimedia applications also require routes satisfying QoS requirements. There is no stationary infrastructure such as base stations in ad hoc networks. Each node in the network also acts as a router, forwarding data packets for other nodes, which in such a network moves arbitrarily, thus network topology changes frequently and unpredictably. Moreover, bandwidth, energy and physical security are limited. These constraints, in combination with network topology dynamics make routing protocols in ad hoc networks challenging (compared to the wired network as well as the mobile IP network) [1–6,17–19].

Goal of this paper is to carry out a systematic performance study for four typical routing protocols of ad hoc networks, which include one distance vector routing protocol DSDV [2] and three on-demand routing protocols AODV [3], DSR [4] and TORA [5]. DSDV is a table-driven protocol based on the classical Bellman–Ford mechanism. The improvements made to Bellman–Ford algorithm include freedom from loops in the routing table. Every mobile node in the network maintains a routing table in which all of the possible destinations within the network and the number of hops to each destination are recorded.

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While AODV, DSR and TORA share the on-demand behavior in that they initiate routing activity only in the presence of data packets in need of a route, many of their routing mechanism are different. AODV uses a table-driven routing framework and destination sequence numbers, DSR uses a source routing, whereas TORA uses a link reversal routing mechanism. Commonly, the latter three have a less routing load and the former has a less end-to-end delay.

The related works of Sung-Ju et al. [7] evaluate five kinds of typical routing protocols (WRP, FSR, DSR, LAR and DREAM). Their simulation works model a network of varying mobility speeds and 50 mobile hosts placed randomly within a 750×750 m area. Radio propagation range for each node is 200 m and channel capacity is 2 M bit/s.

Biao et al. [8], Josh Broch, David A. Maltz, David B. Johnson, Yih-Chun Hu and Jorjeta Jetcheva [9] investigate the routing protocols of AODV, DSDV, DSR and TORA. The former simulation modeled a network of 60 mobile hosts and varying pause times, the latter modeled sceneries with 50 nodes and pause time of 0, 30, 60, 120, 300, 600 and 900 s, respectively.

Das et al. [10] carried out the simulation analysis to AODV and DSR. Their simulation has a model of 50 (the first group of experiment) and 100 (the second group of experiment) nodes at varying pause times.

The above mentioned works consider the simulation model with a constant network size and a varying pause times or mobility speeds. These works do not take into account the influence on the protocols when the mobile node's pause time is invariable but the network size is changing. On the contrary, this paper considers the simulation model with a dynamic network size and an invariable pause time which should be zero under weakest case. So we investigate performances of the routing protocols from different categories under various network scenarios (e.g., different network size, mobility speeds, etc.). This paper systematically discuses the performance evaluation and comparison of four typical routing protocols, AODV, DSDV, DSR and TORA, in ad hoc networks, which take the QoS (delay, jitter, throughput, loss ratio), routing load and connectivity as evaluation metrics.

The rest of the paper is organized as follows. Section 2 presents the simulation model and the performance metrics. Section 3 describes the simulation experiment details, gives simulation results and performance analysis of the typical routing protocols, and concluding remarks are made in Section 4.

2. Simulation model and evaluation metrics

The simulator for evaluating routing protocols is implemented with the network simulation version 2 (ns2) [11]. Our simulation models the network size with 10, 20, 40, 50, and 100 mobile hosts placed randomly within a 1000 m $\times$ 1000 m area. Radio propagation range for each node is 250 m and channel capacity is 2 M bit/s. The node mobility speed is varying between 0 and 40 m/s generated by uniform distribution and the pause time is 0 s which means the node is always moving in the entire simulation period. Each simulation executes for 300 s.The simulation altogether produces 50 kinds of stochastic topologies, each group of nodes corresponds 10 kinds and the collected data is the averaged over those 10 runs.

2.1. Channel and radio model

Up to now there are three propagation models in ns2, the free space model, two-ray ground reflection model and the shadowing model. The free space propagation model assumes the ideal propagation condition that there is only one clear line-of-sight path between the transmitter and receiver. H. T. Friis presents the following equation to calculate the received signal power in free space at distance d from the transmitter [12].

$$P_r(d) = P_t G_t G_r \lambda^2 / (4\pi)^2 d^2 L \quad (1)$$

where P_t is the transmitted signal power. G_t and G_r are the antenna gains of the transmitter and the receiver respectively. $L(L >= 1)$ is the system loss, and λ is the wavelength. It is common to select $G_t = G_r = 1$ and $L = 1$ in ns2 simulations. The free space model basically represents the communication range as a circle around the transmitter. If a receiver is within the circle, it receives all packets, otherwise, it loses all packets. A single line-of-sight path between two mobile nodes is seldom the only means of propagation. The two-ray ground reflection model considers both the direct path and a ground reflection path. It is shown in [15] that this model gives more accurate prediction at a long distance than the free space model. The received power at distance d is predicted by

$$P_r(d) = P_t G_t G_r h_t^2 h_r^2 / d^4 L \quad (2)$$

where h_t and h_r are the heights of the transmitting and receiving antennas respectively. Note that the original equation in [15] assumes $L = 1$. To be consistent with the free space model, L is added here.

The above equation shows a faster power loss than Eq. (1) as distance increases. However, The two-ray model does not give a good result for a short distance due to the oscillation caused by the constructive and destructive combination of the two rays. Instead, the free space model is still used when d is small. Therefore, a cross-over distance d_c is calculated in this model. When $d < d_c$, Eq. (1) is used. When $d > d_c$, Eq. (2) is used. At the cross-over distance, Eqs. (1) and (2) give the same result. So d_c can be calculated as

$$d_c = (4\pi h_t h_r)/\lambda \quad (3)$$

The free space model and the two-ray model predict the received power as a deterministic function of distance. They both represent the communication range as an ideal circle. In reality, the received power at certain distance is a