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Impact of the routing protocol choice on the Envelope-Based Admission Control scheme for ad hoc networks

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ABSTRACT

Envelope-Based Admission Control (EBAC) is an admission control scheme independent of the routing protocol, designed for ad hoc networks with the aim of supporting delay bounds. During the admission of users, EBAC evaluates a known route to determine whether it has enough bandwidth to support the new flow. To do this, the incoming node sends probing packets along a route so that the receiving node computes the envelope of the incoming flow, as well as the service envelope that models the service provided by the network. Based on these envelopes, the receiving node decides whether to admit the new flow. Admission control schemes that are decoupled from the routing protocol can work with any routing protocol. However, characteristics such as the way the underlying protocol deals with link failures or the speed of the route discovery process impact the admission control operation. This paper analyzes the performance of the EBAC scheme when used jointly with four different routing protocols: AODV, DSR, OLSR and DYMO. Results show that in both static and mobile scenarios, joint operation with the AODV protocol achieved the best performance of those evaluated.

1. Introduction

In ad hoc networks, nodes can move and are allowed to join and leave the network at any time. Such dynamic behavior can lead traffic flows to be switched to new routes, thus affecting other ongoing transmissions. Moreover, given that network links are wireless, ad hoc networks are also affected by the typical problems of wireless communications: fading, higher packet loss rate, interference between traffic flows, and even interference between packets of a single flow when these are sent along multihop routes. Providing Quality of Service (QoS) in ad hoc networks is thus a challenging task.

Admission control is a strategy designed to provide QoS guarantees by limiting the number of admitted flows into a network. A new flow is admitted into the network only if the QoS requirements of the incoming flow and that of previously admitted flows can be satisfied. In ad hoc networks, one of the most important design features of admission control is whether or not the control mechanism is coupled with the routing protocol, since the choice of route can impact on QoS provisioning [1]. Admission control schemes decoupled from the routing protocol use routes previously discovered by such protocols and determine whether or not a route has enough resources for the new flow. Two types of such schemes are known: *stateful*, in which intermediate nodes store state information, and *stateless*, in which only source and destination nodes participate in the admission process. Stateless admission control is the simplest scheme, since the burden of the process

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relies only on the source and destination nodes. In these schemes, traffic flows can be switched to a new route when the available bandwidth is insufficient.

Envelope-Based Admission Control (EBAC) [2] is a distributed stateless admission control scheme that requires neither network nor MAC level feedback; moreover, it is able to provide delay bounds to more than one class of traffic. EBAC was designed for pedestrian networks and for density of nodes that avoids network partitioning. The EBAC scheme sends a sequence of probing packets to the destination node, which are used to infer the available bandwidth on the network route between source and destination. The destination node decides on the admission of a flow based on both the envelope of the probing traffic and the service envelope. The envelopes are calculated according to the algorithm proposed by Cetinkaya et al. [3], which was applied to chains of wireless nodes [4]. EBAC has been shown to guarantee delay bounds for two classes of traffic in networks with static nodes [2]. Moreover, EBAC operation was also evaluated in scenarios with mobile nodes.

Although admission control schemes that are decoupled from the routing protocol can work with any routing protocol, the impact of this routing protocol on their operation should always be assessed. Routing protocol performance depends on characteristics of specific scenarios, such as node speed and node density which, in turn, can affect the admission control operation. This paper provides a detailed assessment of the impact that routing protocols have on the performance of EBAC. Four widely known routing protocols were employed in the evaluation: AODV, DSR, OLSR and DYMO. This group includes both reactive and proactive protocols, which allows the evaluation of the performance of the EBAC scheme for different types of routing protocol operation. It is our best knowledge that such investigation has not been carried out before.

The structure of the paper is the following. Section 2 describes the operation of EBAC. Section 3 explains the four routing protocols used in the evaluation. Section 4 *summarizes* the simulation scenario. Section 5 explains the results obtained, and finally, Section 6 concludes the paper.

2. Description of EBAC

EBAC is an admission control scheme designed for ad hoc networks that guarantees delay bounds. The EBAC scheme decides on the admission of an incoming flow by measuring both the arrival and service envelopes of a flow of probing packets. This section describes the operation of EBAC, the estimation of the envelopes of the probing flow and the criteria to decide whether an incoming flow should be admitted or not.

The EBAC algorithm employs the characterization of *envelope processes* to make admission decisions. Given $A(t)$ the cumulative amount of traffic that arrived during the interval $(0, t)$, the process $\hat{A}$ is the envelope of A if, for all t and $\tau,\ 0 \leqslant \tau \leqslant t$

$$A(t) - A(\tau) \leqslant \hat{A}(t - \tau) \qquad (1)$$

Cetinkaya et al. introduced algorithms to calculate measurement-based arrival and service envelopes. The algorithm calculates the arrival envelope as the maximum traffic rate generated by the source node, and the service envelope as the worst service provided by the network.

The admission process of a flow begins when the incoming node starts a flow of probing packets transmitting it at a constant bit rate (CBR) equal to the peak rate of the incoming flow. Relevant information such as the peak rate of the incoming flow, the traffic class it belongs to and the time instant when the probe was sent (*transmission time*) is appended to each probing packet. The destination node stores the transmission and the arrival time of each probing packet and, after a predefined number of probes (or *window size*) received, the arrival and the service envelopes are estimated [5].

2.1. Computation of the arrival envelope

Arrival envelopes characterize the incoming traffic by estimating the aggregate peak-rate envelopes. Let $A[s, s + I_k]$ be the arrivals during the interval $[s, s + I_k]$, then $A[s, s + I_k]/I_k$ is the rate for that particular interval. The peak rate over any interval of length I_k is given by $R_k = \max_s A[s, s + I_k]/I_k$. Thus, the peak-rate envelope is the set of rates R_k that bound the flow rate over intervals of length I_k, and it is described by the pairs (R_k, I_k).

Consider that time is slotted and that slots are I_1 seconds long, which is the minimum interval of the measured rate envelope. Each window consists of T time slots. The peak-rate envelope over the past T time slots, being t the current time, is defined as

$$R_k^1 = \frac{1}{k\tau} \max_{t-T+k \leqslant s \leqslant t} A[(s - k + 1)\tau, s\tau] \qquad (2)$$

for $k = 1, \ldots, T$. Thus, $R_k^1,\ k = 1, \ldots, T$ describes the aggregate peak-rate envelope in time intervals of duration $I_k = k\tau$ contained in the most recent $T\tau$ seconds. The superscript in R_k^m denotes the envelope calculation window, being $m = 1$ the most recent one.

Every T time slots, the arrival envelope is computed using (2). At each iteration, the oldest time window is discarded and the envelopes of the past M windows are retained, including the most recent one, thus $R_k^m \leftarrow R_k^{(m-1)}$, for $k = 1, \ldots, T$ and $m = 2, \ldots, M$.

The variance of the past M measured envelopes is calculated as

$$\sigma_k^2 = \frac{1}{M - 1} \sum_{m=1}^{M} (R_k^m - \overline{R_k})^2 \qquad (3)$$

where $\overline{R_k} = \sum_m R_k^m / M$.

2.2. Computation of the service envelope

The service envelope is calculated by measuring the service received by a traffic flow when its packets are backlogged. When the packets are not queued, only their individual delays are considered.