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General study of jitter mechanisms for metric-based wireless routing protocols

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ABSTRACT

To ameliorate high collision, a nefarious side effect of route discovery stage of reactive routing protocols in wireless networks, jitter mechanisms are proposed which enforce wireless nodes to postpone their transmission for a random amount of time so as to reduce probability of simultaneous transmission. Although it has been shown that jitter mechanisms can dramatically improve reactive routing protocols, it was not until recently that jitter mechanisms have been subjected to study. In this paper, different random distributions are proposed for jittering mechanisms and also shaping function, with the aim of which a simple routing protocol like AODV becomes sensitive to any arbitrary metric, is defined. Comprehensive simulation of routing metrics and jitter mechanisms have revealed that simple modification of a jitter mechanism, which can be even implemented independent of a routing protocol, greatly improves routes discovered by any routing protocol.

1. Introduction

Simultaneous packet transmission in wireless networks has always been a problem, since this leads to collision and potential failure in reception. One of the most prevalent solutions to this problem, particularly when retransmission is possible, is to inform the sender about the collision and ask the sender to retransmit the packet. This simple solution, however, cannot be used always. For instance, during the route discovery stage of reactive routing protocols, where all nodes try to forward route request packets at the same time, collision is almost inevitable [14]. The process of informing the sender about the collision, which requires the transmission of another packet, and retransmission of the packet by sender will only deteriorate the problem of collision in such cases.

RFC 5148 [1] specifically deals with this particular situation. It is recommended that forwarding nodes contributing to route discovery stage postpone their transmission for a random amount of time obtained from a Uniform distribution. This mechanism is called jitter mechanism [4]. In [6,7,9,8] several aspects of RFC 5148 jittering is investigated. In [7,5], a modified version of RFC 5148 was introduced, called adaptive jitter, which accepts a link metric, such as ETX [12]. It has been shown that this simple modification can dramatically improve routes found by routing protocols. It has also been shown that jitter mechanisms can also be built based on other random distributions [2]. In [3], a closed form formula to compute probability of delay inversion of any Uniform-based jitter mechanism is obtained. However, none of these works have comprehensively studied the performance of jitter mechanisms on different metrics while using different random distributions.

Many routing protocols have been devised in recent years to improve certain metrics, such as reliability [15], delay [17], energy [16], etc. The fact that jitter mechanisms can make a simple routing protocol a metric-based one dramatically changes how we look at routing protocols. In fact, by demonstrating that a simple metric-based jitter mechanism allows us to find better routes, with any arbitrary metric, one can simply introduce a simple jitter mechanism for different metrics, such as delay, bandwidth, reliability, etc., instead of designing a new routing protocol from scratch. Note that, although jitter mechanisms change the routes found by routing protocols, it is not necessary to implement them in routing protocol itself. In other words, the delay imposed by jitter mechanisms can be implemented in routing layer, MAC layer or even an abstract layer between these two layers. The only requirement is that the jitter mechanism must know the value of link metric.

In this paper, we study how different random distributions can affect performance of routing protocols. Uniform, Exponential, Pareto and Erlang distributions are comprehensively investigated. Shaping function, a function by which distribution parameters are obtained from link metrics, is also defined and some of its

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key properties are discussed. We will show that a suitable shaping function in tandem with a jitter mechanism gives us a powerful tool to change simple routing protocols, such as AODV and DSR, to metric-based routing protocols without even modifying the routing protocol itself.

In Section 2, reactive routing protocols, delay inversion and different metrics are briefly explained. In Section 3, shaping function is defined based on which many jitter mechanisms, such as Uniform, Pareto, etc., are discussed. Using well-known network simulator, NS2, the performance impact of different jitter mechanisms with different shaping functions is presented in Section 4. Finally, Section 5 concludes the paper.

2. Background

2.1. Jittering and route discovery

In reactive routing protocols, a route is obtained between a sender and a destination whenever needed [13]. When a sender wants to send a packet to a destination while no route is known, it starts a process called route discovery in which a Route Request Packet (RREQ) is forwarded by all nodes until it reaches the destination. The path that the RREQ packet traverses to reach the destination indicates the route which will be informed to the source by the destination.

During route discovery, there would be high contention on channel and consequently unacceptable number of collisions occurs since all nodes want to send RREQ packets simultaneously. As a result, it is recommended that nodes delay their transmission by a random amount of time, called jitter [4].This jitter not only reduces collision, but also can be exploited to find better routes [2]. In fact, by imposing less delay on nodes that has a better link or metric, one can increase probability of finding better routes.

2.2. Delay inversion

Assume a scenario shown in Fig. 1(a). In route discovery stage, each node waits for a random time (jitter) and sends the RREQ packet afterward. Since jitter is obtained randomly, there is no guarantee that the shorter path reaches the destination earlier than the longer path. This gets worse in scenarios where routing metric is not hop count. For example in Fig. 1(b), available bandwidth is considered as a routing metric. However, using a simple jitter proposed in [4], the routing protocol would choose both paths with equal probability, namely 0.5. The phenomenon in which the worse path is selected instead of the better one is called delay inversion [4]. Needless to say, we prefer to reduce the probability of delay inversion as much as possible.

2.3. Routing metrics

In wireless networks, depending on the application and desired quality, one might choose different link metrics, such as bandwidth, delay, delivery ratio, reliability, etc. The way the route metric is computed from its links' metrics are not always the same. In this paper, three different types of metrics are analyzed [10]:

- Additive: The route metric is additive if it is sum of its links metrics, such as delay. The smaller the route metric, the better the route is.
- Multiplicative: The route metric is multiplicative if it is multiply of its links' metrics, such as reliability. Most of the time multiplicative metrics are considered as an alternative form of additive metrics since one can get the logarithm of the multiplication and change it to summation [11]. Hence, we will not present the results of this metric here separately for brevity.
- Concave: The route metric is concave if it is the minimum of its links' metrics, such as bandwidth. In this case, however, greater route metric indicates better route.

3. Jitter mechanisms

Most research in the past focused on jittering mechanisms which obtain a random delay from a Uniform distribution, which is usually called Uniform jitter mechanism [7]. Additionally, it is assumed that no specific routing metric is available and hop count were used for performance comparison. However, it has been recently shown that other distributions can also be used to find better routes, particularly in cases where the routing metric is not hop count [2]. However, it is not clear how the distribution parameters should be set and which distributions are desirable for different types of metrics. In this section, we introduce some definitions and properties which help us answer these questions.

3.1. Shaping function

The key point to a metric-based jittering is to set the parameter (s) of the distribution in a way that imposes less delay on better links. Hence, the RREQ packets of better links reach the destination earlier and consequently a route with better links will be selected. Here, we define some terms to help us categorize different metric-based jittering mechanisms.

- Increasing (decreasing) parameter: Parameter of a distribution is increasing (decreasing) if by increasing its value the expected value of the distribution increases (decreases).
- Shaping function: Any function, denoted by ψ, which can be used to map metric values to a distribution parameter is called shaping function.

Throughout the whole paper, we assume that a link metric, denoted by m, are between 0 and 1 ($m \in [0,1]$) and the greater the metric is, the better the link would be. Given a bounded link metric, such as available bandwidth, one can simply divide it by its maximum to get a value in $[0,1]$. [1] Shaping functions are defined to fulfill our goal which is to impose less delay on the transmission of better links' RREQ packet. Hence, assuming that the parameter of our distribution is decreasing, we define some flexible properties for a shaping function as follows:

- $\psi\prime(m) \geqslant 0$ for $m \in [0,1]$.
- $\lim_{m\to 1}\psi(m) \gg 0$.
- $\lim_{m\to 0}\psi(m) = \epsilon$.

The first property indicates that as a link metric gets better, a jitter mechanism must impose less delay on average. Note that shaping functions are used as a distribution parameter. Hence, if the parameter is decreasing, the shaping function should be non-decreasing. The second property ensures that the delay imposed on links with the maximum possible value of metric should be as little as possible. The third property almost eliminates the worst possible links from route discovery. The second and third properties, however, are network dependent and are not mandatory for a shaping function to work well. For instance, if metrics of all links in the network are almost 1, setting a great value for the second property leads to high collision which is not desirable. It is obvious that for an increasing parameter, shaping function should be non-

[1] Dealing with metrics which are theoretically unbounded, such as delay, is out of the scope of this paper, unless a practical or experimental bound is assumed for them.