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Jitter Consideration for Reactive Protocols in Mobile Ad Hoc Networks (MANETs)
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Abstract

This document provides recommendations for jittering (randomly timing) of routing control message transmission, especially route request dissemination, in reactive protocols of Mobile Ad Hoc Networks, to reduce the probability of collisions, decrease routing overhead, and help finding the optimum paths in the network.

Table of Contents

1. Introduction

Jitter - randomly modifying timing of packet transmissions - is RECOMMENDED to be used in MANETs [RFC5148], to avoid simultaneous packet transmission by neighboring routers - something which might result packet losses due to link-layer collisions.

In [RFC5148], it is RECOMMENDED that in a protocol with regularly scheduled messages, event-triggered message, schedule reset, forwarding, etc, a deliberated random variation in time (jitter) SHOULD be employed. If a message transmission is scheduled, or triggered at time t, a random value between zero and maximum timing variation (denoted MAXJITTER) is chosen to reduce or increase the time of that transmission.

Jitter has been used in NHDP [RFC6130], for periodic HELLO message transmission, and OLSRv2 [I-D.ietf-manet-olsrv2], for triggered and periodic Topology Control (TC) message transmissions.

In reactive protocols such as AODV [RFC3561], DSR [RFC4728] and LOADng [I-D.clausen-lln-loadng], packet loss due to concurrent transmissions by neighboring routers are also a concern, in particular for Route Request message (RREQ) dissemination. This, because RREQ transmissions in neighbor routers are triggered by a single event: reciept of RREQ message to be flooded through the network as part of the route disovery process. However, unlike TC message dissemination in OLSRv2, forwarding of RREQ message has another objective: to discover the best path from the source to the destination. It has been observed, however, that the jitter mechanism as, defined in [RFC5148] and if applied directly, in some cases may result in inferier paths, or unnecessary RREQ retransmissions.

This document analyzes the limitation of [RFC5148] when it is applied to reactive protocols, and then introduces a "window" jitter mechanism, which can help reducing RREQ message retransmission and finding the optimum paths.

2. Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

This document uses the terminology and notation defined in [RFC5148].

3. Applicability Statement

This document describes a jitter mechanism that is applicable to the Route Discovery process in reactive MANET protocols, such as Route Request (RREQ) flooding in AODV [RFC3561], DSR [RFC4728], LOADng [I-D.clausen-lln-loadng], or AODVv2 [I-D.ietf-manet-aodvv2].

The jitter mechanism, as described in [RFC5148], is originally intended for application where the underlying medium access control and lower layers do not provide effective mechanisms to avoid packet collisions when faced with concurrent transmission by neighboring routers. This document handles the situation of "Message Forwarding", described in section 5.3 of [RFC5148]. In addition to collision avoidance by way of a random delay in transmission of RREQ messages, the document also considers:

Route Discovery of Optimal Paths When RREQ messages are flooded through the network, the path cost (e.g., hop count or any other link metrics) is also accumulated and recorded. The destination of the RREQ will reply it with a Route Reply (RREP) message. However, the RREQ copy that arrives first may not always be the one which has traversed the optimal path, with respect to the metric used. It has been observed that, in some cases, this is exacerbated by the use of [RFC5148].

Route Discovery Overhead In classic flooding, duplicate message are dropped by intermediate routers, and not retransmitted. However, for RREQ flooding, in which the cumulated path cost is carried in the RREQ, intermediate routers may need to transmit the same RREQ message multiple times, when the shortest (according to the metric in use) path is desired. For example, when an RREQ arrives from the same source to the same destination, and with same sequence number as previously forwarded RREQ, but with a lower path cost. Again, this is exacerbated by the used of [RFC5148].

This document suggest a "window jitter" mechanism, which can help discovering the optimal paths in reactive protocols, and, simultaneously, can reduce the route discovery overhead, with the cost of slightly increasing the route discovery delay.

4. Problem Statement

[RFC5148] recommends applying jitter to a forwarded message by reducing the time of its emission by a small, random duration in the mediums where transmission collisions are possible. This delay is recommended to be generated uniformly in an interval between zero and MAXJITTER. This has been show to work well in message flooding,

where the goal simply is that all routers get a copy of the unmodified message, such as is the case for TC messages in OLSRv2 [I-D.ietf-manet-olsrv2].

In reactive protocols, RREQ message from a source are flooded through the network, carrying a "path cost" field, modified by intermediate routers when the message is forwarded. This allows the destination sought through the Route Discovery process to identify which copy of the RREQ has traveled through the "least cost path" (according to the metric in use in the network), and select that path for generating a RREP and installing a routing path. It is, therefore, unfortunate if the copy of the RREQ arriving via the "least cost path" is received later than a RREQ over a path with a higher cost due to inappropriate application of a jitter mechanism.

Consider the topology shown in Figure 1, and assume that router A floods an RREQ to identify a path towards router D. Hop count metric is used in this example. If no jitter is used, the RREQ would reach router D through path {A-E-D} faster than the path {A-B-C-D}, assuming that processing time and transmission time at each intermediate router (Ti) are similar.

If [RFC5148] is applied, a uniform random distribution [0, MAXJITTER] is used at each hop to determine an additional delay before retransmission, see [RFC5148] section 5.3, the RREQ copy sent through the longer path (in number of hops), may reach the destination faster than the RREQ over shorter path. For example, in Figure 1, the MAXJITTER is 500ms (MAXJITTER is normally chosen to be much greater than transmission time Ti, to avoid collision. Therefore, Ti is neglectable if jitter is used). If Jitter at E (JitterE) is chosen to be 300ms, JitterB is 100ms, and JitterC is 150ms, the RREQ though the longer path (A-B-C-D) would reach D faster than the shorter path (A-E-D). This phenomenon is called "delay inversion".

```
                   JitterE=300ms
          /----- E------\
         /               \
       A                  D
         \               /
           B--------C---/
       JitterB=100ms  JitterC=150ms
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Figure 1: An example of delay inversion. The RREQ through longer paths may traverl faster, if jitter in RFC5148 is used.

In this case, router D would reply to the RREQ with an RREP that

advertises path (A-B-C-D), which is suboptimal. When the RREQ traversing (A-E-D) reaches router D, router D would reply again to the cope of that same RREQ again with the shorter path (assuming shorter path is preferred).

If router D is not the final destination of the RREQ, but only an intermediate router that forwards the RREQ message, there are two possible approches used in different protocols:

o For AODV [RFC3561] and DSR [RFC4728], the intermediate routers only forward the first copy of the RREQ received - all the later ones are discarded, even if the later one carries paths with lower costs. This would lead to sub-optimal paths discovered.

o For LOADng [I-D.clausen-lln-loadng], the intermediate routers would always retransmit the RREQ carrying better paths that comes later. In the example of Figure 1, router D would retransmit the RREQ received from JitterE also, which result in one more flooding (not only at router D, but to the whole network).

The example above illustrates that a "naive" application of [RFC5148] for reactive protocols may present some drawbacks, in terms of path sub-optimality and/or control traffic inefficiency.

The "delay inversion" phenomenon stems from the fact that the delay imposed by intermediate routers can not really reflect the link metrics of related routers. Even jitter is not used at all, it will happen -- and the application of jitter amplified such phenomenon. Using other link metrics, or reduced topology mechanisms (like Connected Dominating Set) will not mitigate the problem. On the other hand, the delay inversion has direct relationship with the network size -- it is more often as the network grows [NBis2013].

5. Reactive Jitter

In order to reduce the impact of the "delay inversion" phenomenon, described in Section 4, the notion of window jitter introduced in this section. The purpose of "window jitter" is to attempt at "penalizing long paths" more than short paths (in the aspect of hop count, or other metrics), and it is RECOMMENDED that this be employed for Route Discovery (RREQ flooding). In addition to the MAXJITTER, a lower bound of jitter is applied, with this lower bound depending on the metrics used.

5.1. Window Jitter for Hop-count Metric

For protocols like AODV [RFC3561], DSR [RFC4728], LOADng [I-D.clausen-lln-loadng] or AODVv2 [I-D.ietf-manet-aodvv2], the hop-count metric is supported by default, i.e., a path with a lower hop count is better than a path with more hop counts.

When a router forwards an RREQ message, it SHOULD be jittered by delaying it by a random duration. This delay SHOULD be generated uniformly in an interval between MAXJITTER/2 and MAXJITTER.

5.2. Window Jitter for Generic Metric

While the hop count metric is straightforward and easy to implement, operational experience has revealed that the used of hop-count as routing metric often leads to unsatisfactory network performance. Reactive protocols like LOADng [I-D.clausen-lln-loadng] thus support using metrics other than hop count, such as ETX [I-D.funkfeuer-manet-olsrv2-etx] and ETT [I-D.rogge-baccelli-olsrv2-ett-metric].

For those generic metrics, given a link quality indicator LQ between (0,1) (1 indicates highest quality links), jitter values SHOULD be assigned under a generalized window jitter distribution uniformly within the interval between (1-LQ)MAXJITTER and MAXJITTER.

6. Implementation Status

This section records the status of known implementation of the protocol defined by this specification, based on a proposal described in [RFC6982]. There are currently one publicly-known implementation of window jitter specified in this document.

6.1. Implementation by Ecole Polytechnique

This implementation is developed by the Networking Group at Ecole Polytechnique and applied to LOADng [I-D.clausen-lln-loadng] for RREQ message flooding. It can run over real network interfaces, and can also be integrated with the network simulator NS2. It is a Java implementation, and can be used on any platform that includes a Java virtual machine.

The implementation is based on the -00 revision of this document, and makes up only a handful of lines of code - in addition to the core LOADng protocol implementation. Both analytical and simulation results have been published in [IEEE_WiOpt2013] and [NBis2013]. The results show that if the shortest paths are desired, the window

jitter can reduce the RREQ flooding overhead by 50%, as compared to a naive application of [RFC5148].

7. IANA Considerations

This document contains no actions for IANA.

8. References

8.1. Normative References

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