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Data Bit-Rate Instability in Wireless Multi-Rate Ad Hoc Networks*

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Abstract

Wireless Ad-hoc single-rate environments typically use a Distance Vector routing with a metric based on the minimization of the hop-count. In practice, the technique of minimizing the distance does not reward in the case of multi-rate, therefore it may be preferable to use protocols privileging the link's transmission speed instead of the minimum distance. Our study aims toward the stability of the link in a wireless high mobility environment; we explore and hypothesize how to privilege, in the choice of routes, the stablest link.

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1 Introduction

With the advent of wireless networks based on IEEE 802.11 Protocol [7] [8] and especially with the definition of the new draft n, it is possible to deal with a variable-speed link going from 1 to about 300 Mbps [10]; besides, considering that mobile networks have the peculiarity of movement – which makes link’s speed highly variable and therefore very unstable, stability of routes becomes a difficult undertaking.

Furthermore, as for its intrinsic nature, the same protocol IEEE 802.11 introduces a considerable network overhead to control the transmission at the expense of throughput, so we think that choosing a stable routing – mainly considering stable links – is preferable to take into account only link’s length.

2 Ad-Hoc Networks’ Routing Problem

2.1 Traditional routing protocols for ad-hoc networks

Among the traditional routing protocols, particularly among Reactive Protocols [1], the Ad-Hoc On-demand Distance Vector (AODV) [3] [4] [5] – being based on the minimization of hop-count – prefers very long links (in the sense of distance between two network nodes), so decreasing the network’s total throughput. If, indeed, the shortest link would be chosen the transmitter node would reach the receiver with a stronger signal, which corresponds to a higher link’s throughput. This means that on equal distance, you must choose a larger number of nodes and this contrasts minimisation of the hop-count.

Among the routing protocols of proactive type [1] called “Proactive Routing Protocols”, instead, the OLSR (Optimized Link State Routing Protocol) [2] [6] is much closer to the solution we’re going to propose, because it manages the entire network topology, considering a predominant type of link

and its speed.

2.2 Traditional reactive routing

Wireless ad-hoc networks are generally composed of nodes such as notebooks, PDAs, mobile phones. The characteristic of ad-hoc networks is to have frequent changes in topology. In addition, to keep track of topology, there is a significant commitment of resources and a considerable overhead.

The protocols of Reactive type were designed for these environments. The aim is not to keep track of the network topology. Let us see the process [2].

If a node needs to reach a destination, it starts a Discovery Process to find the path. This process begins through the transmission – by the source node – of broadcast messages of Route Request (RREQ) type, with TTL set to 1 [11] [2]. This RREQ message will only pass through a single node because of its TTL set to 1.

Each message has a sequence number, so that only the first message is considered, while its subsequent copies are discarded. When a node receives the first copy of a RREQ from a source node, it stores the address, thereby establishing a return path (*reverse route*). When the first RREQ reaches the destination, a reply message of type Route Reply (RREP) is sent to the source through the return path (reverse route). This type of protocol is generally efficient for a single rate network. In a multi-rate network, however, what counts is not to minimize the number of jumps to reach a destination, but the total throughput on a given routing. An existing technique taking into account not the number of hop-count, but throughput is the MTM (Medium Metric Time) [9] [2]. In this technique a cost inversely proportional to the speed of the link is established, then the choice is based on link's minimum cost.

Our study fits in this area; we believe that it is not enough to consider, in choosing the path, only the cost of the link, but you should also (and perhaps especially) consider its stability.

3 An Improvement Proposal

3.1 The problem of routing instability in high mobility networks

Although existing routing techniques are of indisputable validity, as a result of lengthy trials conducted in wired networks, a problem – in our opinion – which causes the degradation of wireless ad-hoc networks impacting on the discovery route processes is the same routing instability, given that we are dealing with high mobility networks. What do we mean by *routing instability*?

Let us consider a node represented by a mobile phone transmitting while in movement and think how variable is the signal received from a surrounding node as the issuer node moves in a closed or open environment. The level of the received signal, changing constantly, causes a continuously variable ratio of Signal-to-Noise (S/N), altering the bit-rate and consequently the cost of the link. This variability would lead to a continuous instability of routing, causing a continuous search of the “best path”. This implies an overhead’s increase impacting greatly on the performance and throughput of the entire network. We propose a technique that keeps track of this instability, so as to avoid too unstable links in the process of discovery route.

3.2 Keeping track of routing instability

Keeping the memory of instability means understanding how unstable are link connections between nodes. The idea is to have a table maintaining information associated with each link on its speed “transitions”. With the word “transition” we mean the link’s moving from one speed to another. We can imagine a simple table (Table I) in which each link of the node is associated with its number of transitions.

Node's link	Number of transitions
L_1	N_1
L_2	N_2
L_3	N_3
\dots	\dots

Table 1: Link transitions of a node

3.3 Defining the instability index and threshold

Let us now define what causes the increase in the number of transitions associated with the link. In order to record the link's instability we omit all low speed transitions, that is those which do not make a significant degradation of performance link. Our idea is to record a transition whenever the link gets an increase in speed over twice or falls to less than half its value. So if, for example, V_1 is the speed on the link before the change and V_2 the speed after the change, we'll keep track of transition when:

$$V_2 > 2 \cdot V_1 \quad \text{or} \quad V_1 > 2 \cdot V_2 \quad (\text{i.e. } V_2 < \frac{V_1}{2})$$

Summing the number of transitions of a link does not provide any significant information if it is not compared to a period of observation. All this leads to a concept of *frequency*. For example, if N is the number of speed transitions between the instant t_1 and the instant t_2 , the frequency F will be:

$$F = \frac{N}{t_2 - t_1}$$

3.4 Defining the observation's time interval

To establish a statistical time interval is not simple. You can guess that the time interval will be inversely proportional to the average speed of the links and directly proportional to the number of nodes. So, given a network of N

nodes, with links' average speed V_m , you can say that:

$$t_2 - t_1 = \frac{N}{V_m}$$

After this interval the various counters (column "Number of transitions" in Table 1) are zeroed.

To end our assumptions, a maximum threshold of the number of transitions in time (secs) remains to be defined. If, for example, one considers a time interval of 300 secs, a possible threshold value of the number of transitions is a transition every 15 secs. In a nutshell we'll say that, if the number of transitions is greater than 1 every 15 seconds, the network is *unstable*. In summary: if $F > 0.07$ ($\frac{1}{15}$) we'll say that the network is unstable.

Finally, to better calculate this frequency, Table 1 needs additional information, so that for each link the moment when the counter has been reset is recorded. Table 1 is then accompanied by a *timestamp* for each link, turning in Table 2 below:

Node's link	Number of transitions	Timestamp
L_1	N_1	hh:mm:ss
L_2	N_2	hh:mm:ss
L_3	N_3	hh:mm:ss
...

Table 2: Links' timestamps

3.5 How changes the choice of *best path* in the discovery route.

When deciding on the best path we propose three theories of choice, called "Link Stability", "Link Rate" and "Rate in Stability" described below in detail.

3.5.1 Link Stability

This technique, as the term shows, prefers the stability of the link and then in the choice of routes, to build the path, it excludes a priori all links having a frequency F above a certain threshold. Returning to our example, if $S = 0.07$ is the threshold corresponding to a transition every 15 seconds ($\frac{1}{15}$), all links having $F > 0.07$ will be excluded from the choice.

All this, however, could create malfunctions unless you consider the fact that it is true that you must choose the stablest link, but a stable link could also be one with a zero (i.e. not working) bit-rate. Therefore, a minimum threshold should be set of link's speed below which the choice cannot be done, even if the link is very stable.

So, if we consider a minimal speed value such as $V = 10$ Mbps, the thresholds to keep under control are two: $F > 0.07$ and $V > 10$ Mbps.

3.5.2 Link Rate

In this technique stability becomes of secondary importance: the speed of the link is in any case to be preferred. So, when choosing routes for the construction of the best path, only on equal link's cost (at an equal speed) the stablest link will be chosen.

But what we mean by *equal speed*?

First, it should be noted that from a practical point of view having two links of the same speed may not correspond to reality, if not for a purely random case. Therefore we'll call two links of "equal speed" if the difference in speed between them is no more than 20%. E.g.: if the link L_1 has a bit rate $V_1 = 100$ Mbps you can say that a second link L_2 has the same speed V_2 if:

$$80 \text{ Mbps} \leq V_2 \leq 120 \text{ Mbps}$$

Coming back to our technique the algorithm will choose, only under such conditions – among two links of equal speed – the more stable. To define

this stability the same considerations outlined in the previous technique will be done.

3.5.3 Rate in Stability

We have also planned for a third technique that provides a hybrid choice between stability and speed. Because we want to find a balance between the two, our effort is to define a model including both above said considerations.

The key idea is to keep both parameters – the speed V and the frequency of transitions F – within a range. Therefore, the speed V of a link must be included in the range:

$$V_1 \leq V \leq V_2$$

where to define the range we can theorize that V_1 is a minimum threshold of acceptability as defined by the user, while V_2 may be the maximum limit of the real speed of the physical carrier.

A similar consideration for the frequency F , where we define the range:

$$F_1 \leq F \leq F_2$$

In this case the definition of F_1 may derive from a statistical study of the network in question, while F_2 can be user defined; this limit is the known stability threshold beyond which the link is declared unstable. Moreover, synthesizing the two sizes in a single K magnitude, we can say that:

$$K = \frac{V}{F}$$

namely K is a parameter directly proportional to link's speed V and inversely proportional to the frequency of transitions F . The size K will be a value appropriate for implementing a possible algorithm.

Turning to an example, an acceptable (to current technologies) range of speed (in Mbps) can be:

$$10 \leq V \leq 50$$

and for the frequency of transitions F :

$$0.017 \leq F \leq 0.07$$

where 0.017 is the best case for transitions and it means a transition every 60 secs, while 0.07 – which corresponds to a transition every 15 secs – is the worst case.

Turning to magnitude $K = \frac{V}{F}$ and considering that the best case for speed is $V = 50$ Mbps and for frequency is $F = 0.017$, we can calculate $K = 2941.18$. While in the worst case, with $V = 10$ and $F = 0.07$, will be $K = 142.85$. Therefore, it follows that the range on the magnitude K will be defined as follows:

$$142.85 \leq K \leq 2941.18$$

4 Conclusions

The simple techniques exposed adapt to any type of wireless ad-hoc network and any kind of speed, by the definition of the exposed parameters. Therefore, we believe that this methodology can be implemented in any type of network environment, even in networks with very high density of nodes, as wireless networks in delimited environments such as university campus, airports, shopping malls, etc.

It would be useful to study how these techniques – when implemented – impact on the energy consumption of nodes. This study would not be aimed at finding an absolute value of absorbed energy, rather a percentage value relative to the network overhead introduced.

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