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Link Disconnection Entropy Disorder in Mobile Adhoc Networks

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Abstract: **In Mobile Ad-hoc Networks, nodes move freely causing an interruption in communications. This communication interruption can be accounted in a time lapse to an entropy to connection or disconnection; the combined entropy disorder of a node's links describe how suitable a node is to communicate to neighbors. This entropy disorder is tightly coupled to mobility and communications factors such as node's speed or data traffic saturation. In this paper, we analyze the relationship between speed and traffic saturation into a disorder in link entropy with a focus on disconnection, namely Link Disconnection Entropy Disorder (LDED). The findings indicate a high LDED value to nodes with high speed.**

Keywords: **Adhoc Networks, Entropy Disorder, MANETs, Node Mobility, Node reliability.**

I. INTRODUCTION

Mobile Ad-hoc NET works:

Multiple mobile devices form a Mobile Ad-hoc Network or MANET; with no need for a fixed infrastructure; capable of self-organize; and easy to deploy in an instant [1]. Each member helps others forwarding packets to nodes out of reach; Making the MANETs useful and ideal for some military and commercial applications. All this characteristics give the opportunity to work with applications like scouting or swarming; disseminating communication or sensory detection capabilities in a localized area.

MANETs provide the possibilities for applications where a fixed infrastructure is not available, by forming a dynamic and extemporaneous one. Usually for special or customized application. In the battlefield, autonomous agents could be able to assist in communications and data gathering for intelligence, like surveillance, damage assessment, and other tactical needs. In civilian life, some proposals are published; one of this proposals is a dispatch system for taxis [2] while other is a complete framework for applications to monitor the neighbourhood [3] . The vehicular industry is one to benefit using in-vehicle network applications as in vehicle-to-vehicle communications. Whatever the application, some can benefit from knowing the mobility level of the devices in the network, mostly to adapt and adjust.

Measuring in MANETs:

The node mobility and other factors like channel saturation could disturb the whole network. Since the nodes are free to move, the topology in MANETs changes as the mobile devices moves, affecting data rates and links to other nodes or disappearing established links of communication [4]. Understanding this behaviour could prepare us to adapt or just know how the system is performing. Mobility Metrics provides feedback from the network by quantifying the effect of node movement [5]. Some metrics uses the location, speed, or distance to evaluate mobility [6], [7], costing a great deal in CPU usage and power consumption among other resources like sensors.

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The use of creative metrics is needed to assess mobility with less use of resources. Power consumption could be minimized by using data from the device with less CPU utilization and lowering resource use. These creative metrics describe link or path stability or link behaviour [8], [9].

Ad-hoc metrics could derive from the behaviour of links caused by movement; by observing the changes in characteristics of a link directly affected by mobility. As a node moves, links to near neighbours change, so as the following characteristic. When a link is completely stable, the communication is at optimal. When a connection keeps breaking half the time, then half of the information passing thru is not delivered or retransmitted giving a value of degradation of the link. ETX [8], [10] uses the ratio of forward and reverse delivery ratio of the link while link duration metric (LD) [11] uses the term of each existing link between nodes. Some others evaluate the rate of change of a characteristic [6].

A metric which can quantify the movement of a node in a relationship with neighbours could help to understand the dynamics of the network. When two networks use different mobility models with no point of comparison, a mobility metric could be the point to compare. If a routing protocol uses the metric, it could support to select the most stable route from a group of routes. The metric should describe the dynamics of the nodes in the network.

A practical mobility measure needs to cover some real world characteristics [12]:

- Must apply to real nodes, has to be computable in a distributed environment
- Adapt to measure performance locally
- Numerically quantify the quality of a link
- Evaluated in real time

2. MATERIALS AND METHODS

Entropy and Link disconnection entropy disorder:

Entropy is a versatile measure [13] used in different fields. This measure could be used and adapted in chemistry, biology and medical research [14], animal and human behaviour [15]; in computer science is used in analysis of complex systems and information, Image analysis, and computer networks [6], [16].

Entropy-based metrics in ad-hoc networks turns a rate of change or behaviour to a measure; usually to entropy, order, or disorder. Entropy presents the uncertainty and a measure in a system [16]–[18]. The majority of Entropy measures in Ad-hoc networks rate the changes in link characteristics such as breakage or duration. When a measurement is big on entropy means high rates of change [19].

One of the faces of entropy is disorder [20], [21]. Disorder is defined as [19], [22]

$$\Delta = S/S_{max}$$

Where S is the Boltzmann-Gibbs-Shannon entropy [23]

$$S \equiv -k \sum_{i=1}^{N} p_i \log_2 p_i$$

Using pi as the probability of state i of the N states in the system, the Boltzmann constant is represented by k.

Smax denotes the maximum entropy of a system with equiprobable distribution of pi

$$S_{max} = k \ \log_2 N$$

The link breakage is used to measure Link disconnection entropy disorder by Implementing a beacon to track the link breakage between neighbours, where only the neighbours in range could capture the beacon, but when the neighbour is out of range the beacon is lost creating a lost link event as in figure 1, links in time t are broken in t+1. When a beacon is received a successful link is marked as 1 in time t, a register of beacons received or lost is used to evaluate the microstates in time window T. The time window T is a sliding window where the data is recollected in the last T seconds.

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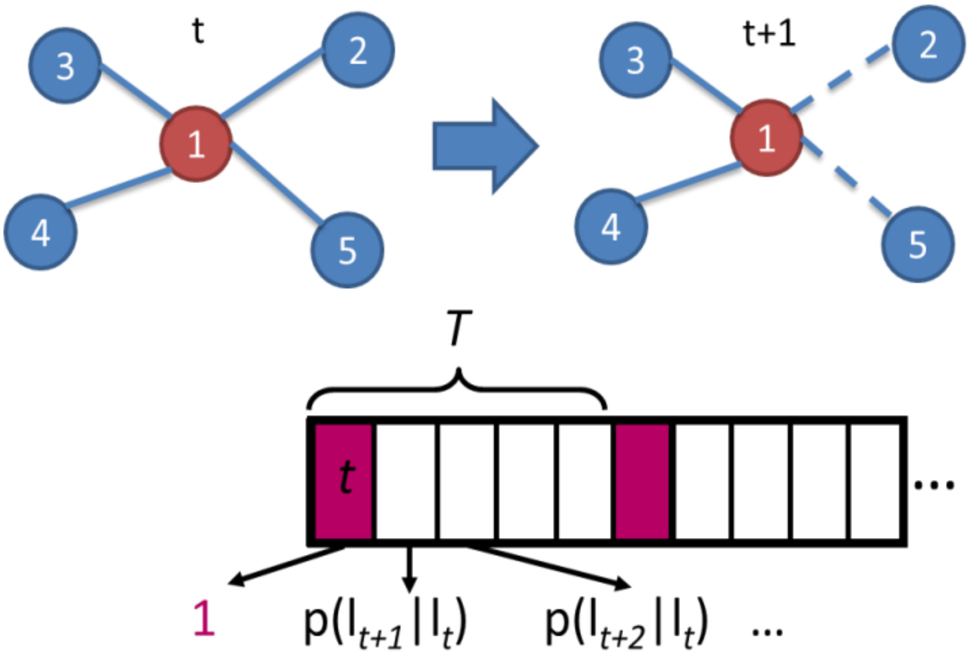

Figure 1: Node observation time window

When a node moves along the network, link breakage, and new connections are made as in figure 2. If the node passes in range of a neighbour a new link is created and observed until complete link breakage in time window, if the link is maintained thru the time window the link disconnection entropy disorder is low meaning not much change is made, but if the link is lost and regains in time, the link disconnection entropy disorder will elevate. To make the link disconnection entropy disorder about the node, all links to neighbours are used to calculate the disorder.

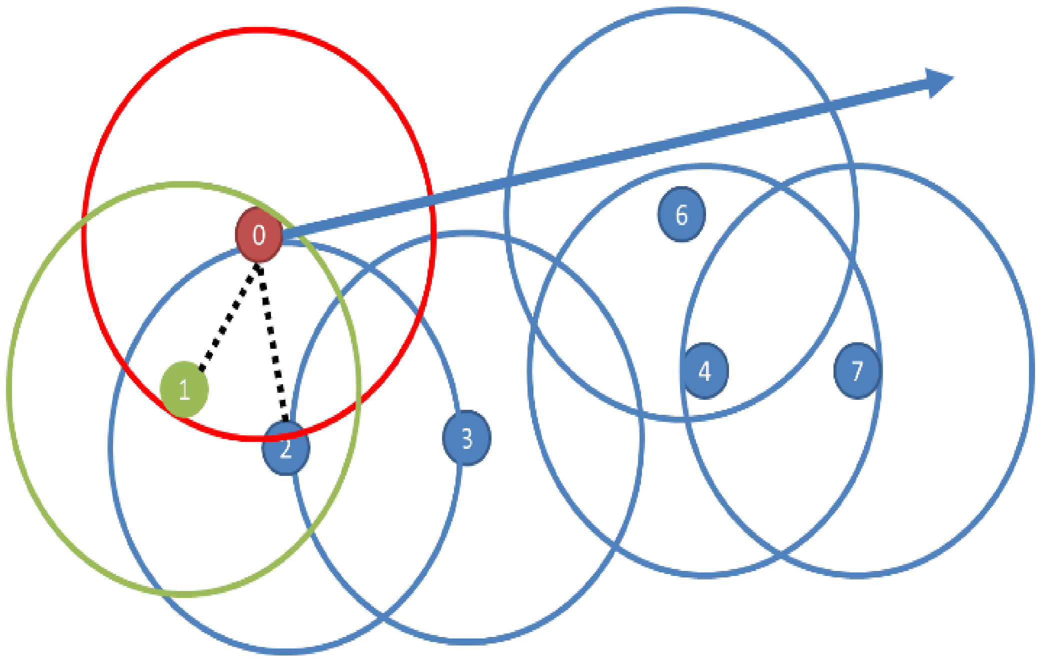

Figure 2: Node moving thru network

The link disconnection entropy disorder index proposed here has all the characteristics of a practical mobility metric. Easy to implement in real nodes due to simple calculations, it does not require a high power processor; each node evaluates own index, distributing the processing of all direct links.

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The simulation:

In order to test the link disconnection entropy disorder behaviour in a controlled environment, a simulation was implemented. Using Omnet++ discrete network simulation as the framework; extended with libraries to create and control mobility, 50 Nodes with Wi-Fi capabilities was used, using the Trivellato table for a realistic simulation. Each node moves independently using RandomWaypoint mobility model.

To measure the Link disconnection entropy disorder, each node has a time window of 4 seconds and a beacon every 0.5 seconds were used. In this time window is recorded only the last 4 seconds of beacons, refreshing the metric every 2 seconds.

Different scenarios were used for observing the effect of speed on link disconnection entropy disorder. In each one a speed was selected and run for 600 seconds. The selected speeds were 0.2, 0.5, 0.7, from 2 to 10, 12, 14, 16, 18, 20, 22, 24, 26, 28 meters per second.

The standard G.728 (16 kbps) is used to stress the network when. With a payload of 60Bytes, containing 30 seconds of audio; sending 33.3 packets per second. This configuration is emulating a constant bit rate of audio for the duration of the simulation.

3. RESULTS

In figure 3 the graph shows the increase in Disorder as Traffic and speed increases; the group was separated by the source to display the effect of speed.

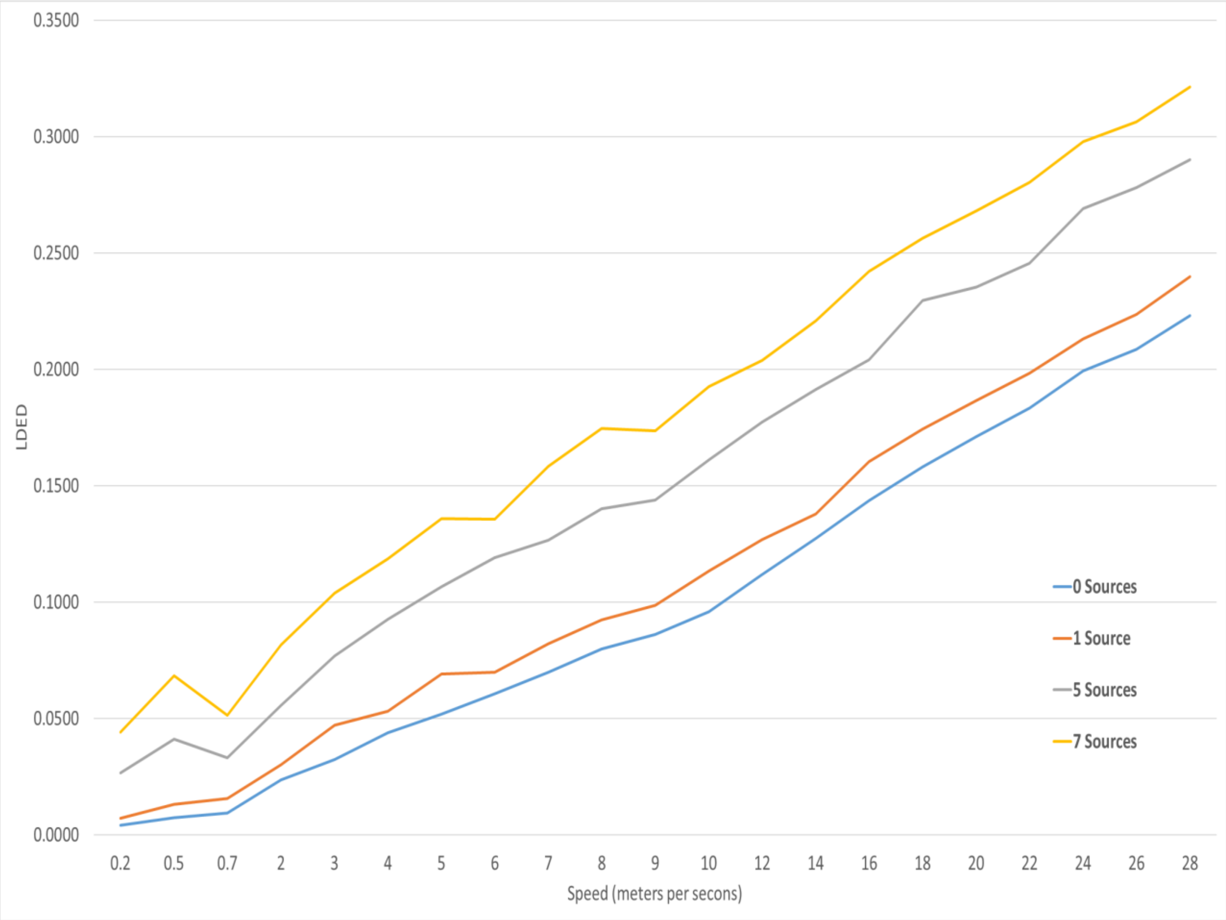

Figure 3: Link Disconnection Entropy Disorder with 0,1,5,and 7 traffic sources

In figure 4 we can see the relationship in Link Disconnection Entropy Disorder to the packet delivery ratio, trending in a logarithmic form.

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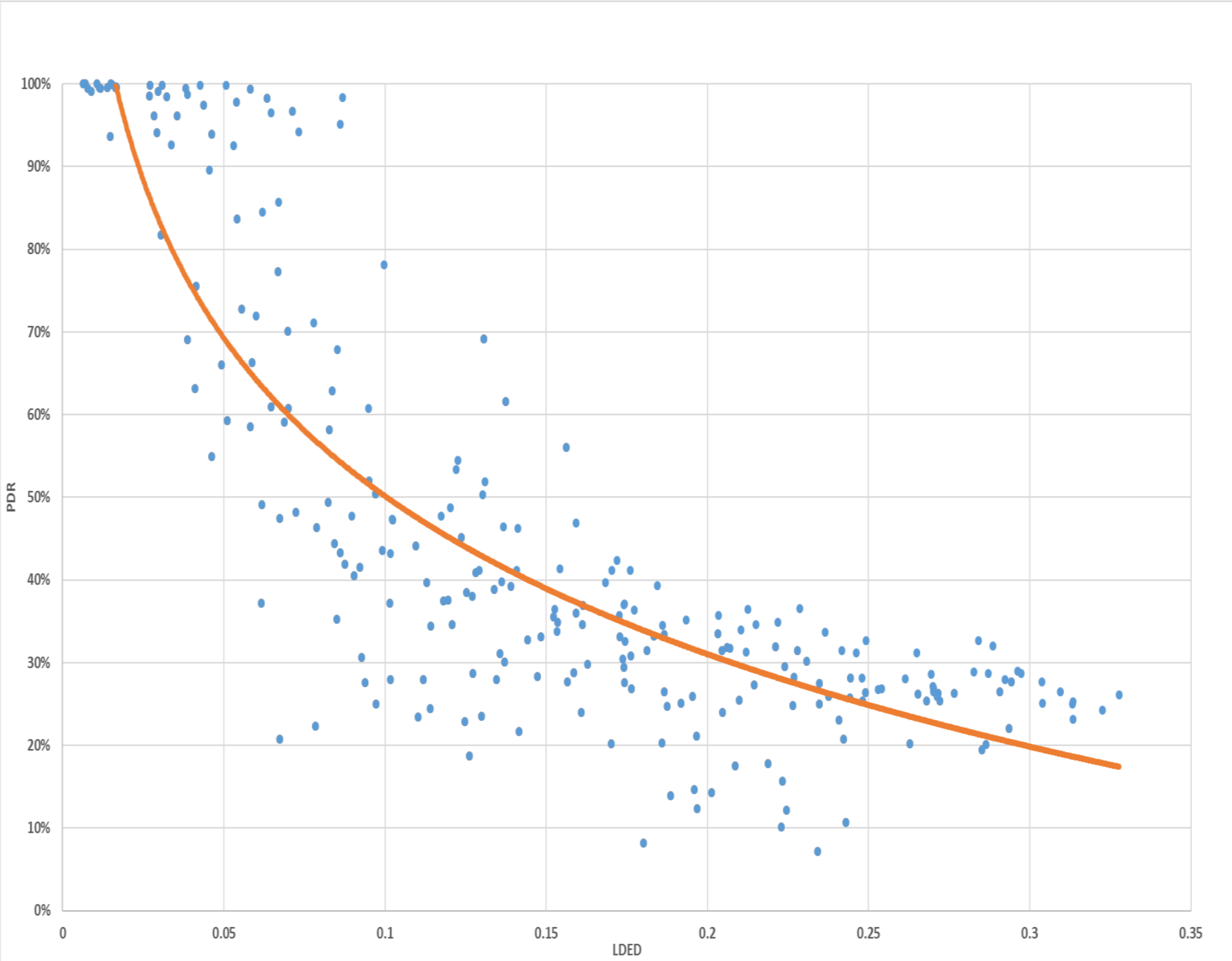

Figure 4: Packet Delivery Ratio / Link Disconection Entropy Disorder graph

Table 1 shows link disconnection entropy disorder results in 3 simulation runs for each traffic saturation using 21 speeds.

Table 1: Link Entropy Disorder by speed and traffic saturation.

	Speed (mps)																				
LDED	0.2	0.5	0.7	2	3	4	5	6	7	8	9	10	12	14	16	18	20	22	24	26	28
0 Sources	0.00413	0.00777	0.00934	0.02212	0.03121	0.04226	0.05220	0.06011	0.06981	0.07867	0.08781	0.09676	0.11130	0.12749	0.14239	0.15760	0.17121	0.18288	0.20104	0.20883	0.22415
	0.00406	0.00743	0.00988	0.02582	0.03279	0.04310	0.04954	0.06088	0.06992	0.07934	0.08521	0.09650	0.11214	0.12679	0.14518	0.15720	0.17249	0.18407	0.19870	0.20777	0.22070
	0.00415	0.00713	0.00863	0.02291	0.03303	0.04597	0.05388	0.06076	0.06980	0.08161	0.08548	0.09436	0.11190	0.12794	0.14342	0.15986	0.16988	0.18315	0.19835	0.20919	0.22483
1 Source	0.00707	0.01393	0.01468	0.02832	0.05406	0.04629	0.06166	0.06742	0.08511	0.09047	0.10171	0.11196	0.12474	0.13753	0.16084	0.17291	0.18654	0.19675	0.21445	0.22290	0.24302
	0.00785	0.01501	0.01536	0.03549	0.04111	0.05107	0.06738	0.06986	0.08238	0.09272	0.09707	0.11403	0.12986	0.13457	0.16138	0.17011	0.18745	0.19669	0.21877	0.22448	0.23424
	0.00642	0.01058	0.01666	0.02691	0.04625	0.06186	0.07850	0.07236	0.07871	0.09382	0.09721	0.11427	0.12612	0.14147	0.15853	0.18025	0.18594	0.20132	0.20619	0.22326	0.24216
5 Sources	0.01649	0.05825	0.02925	0.04143	0.08367	0.09216	0.08763	0.10237	0.12079	0.13574	0.13909	0.16289	0.17428	0.19538	0.20471	0.22688	0.23085	0.24440	0.26530	0.27153	0.29420
	0.03238	0.02719	0.05397	0.06674	0.06457	0.08436	0.11294	0.12708	0.13395	0.13700	0.14840	0.15935	0.17636	0.18671	0.20457	0.22406	0.24087	0.24428	0.27211	0.28632	0.28514
	0.03095	0.03816	0.01641	0.05881	0.08273	0.10155	0.11951	0.12810	0.12535	0.14737	0.14429	0.16128	0.18135	0.19178	0.20332	0.23754	0.23469	0.24819	0.27015	0.27654	0.29077
7 Sources	0.03876	0.08617	0.05307	0.06004	0.12021	0.10218	0.13615	0.12913	0.15266	0.17725	0.17266	0.18446	0.19339	0.22183	0.23659	0.24615	0.27005	0.28267	0.29737	0.30945	0.32774
	0.05078	0.07317	0.06706	0.09965	0.08966	0.12263	0.13033	0.13678	0.15422	0.17200	0.17444	0.20708	0.21511	0.21209	0.24797	0.25304	0.26940	0.27118	0.30391	0.31340	0.31346
	0.04269	0.04557	0.03376	0.08515	0.10169	0.13106	0.14118	0.14087	0.16839	0.17428	0.17407	0.18616	0.20337	0.22857	0.24168	0.27009	0.26501	0.28715	0.29229	0.29618	0.32258

Table 2 contains the ANOVA analysis of Table 1, focusing with p-value and ETA squared.

Table 2: ANOVA using Traffic and speed as variables

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*	*ETAsqr*
Traffic	0.278014	3	0.09267	1630.33	6E-124	2.6584	0.15572
Speed	1.482863	20	0.07414	1304.37	5E-173	1.6334	0.83058
Interaction	0.014909	60	0.00025	4.37152	2.8E-14	1.3981	0.00835
Within	0.009549	168	5.7E-05				
Total	1.785335	251					

4. DISCUSSIONS AND CONCLUSION

The effect of mobility in connections is evident, and is aggravated when a route of packets involves several nodes, as one node forward the packets thru others; Selecting the best nodes to communicate is essential. LDED measures the reliability of each node in a route, or a single node finding a point of reference for a better node selection.

This metric takes in account the packets lost in a time windows and create a measure to evaluate the quality of a node, subject on the links to surrounding neighbours, evaluating how trustworthy a node could be to pass packets to a near neighbour.

The metric is evaluated at each node; assessing the links to the closest neighbours and calculate how much disorder is in the links with them. If all nodes move at the same speed, the links between have similar behaviour, and the average Disorder is similar thru the simulation time.

In figure 3 the increase in node speed characterize an increase of links getting broken and new ones created by reaching other nodes, this change elevates the disorder of the node.

Link breakages caused by channel saturation have the same effect. But in this case, the cause is different; channel saturation makes the beacon mechanism to loss some packets and taking this as a loss link.

By introducing traffic and plotting the packet delivery ration against the Disorder of the network, we could observe in figure 4, an area between 0 and 0.05 of a typical behavior of PDR in multi-hop ad-hoc networks, but when 0.8 is exceeded a high loss is taking toll. If nodes have such high disorder, it is better not to include them in a route, as they will cause a low PDR.

As two mayor factors are reflected in the metric, a two-way ANOVA test and a size effect analysis was conducted, the table 2 shows the results. The statistically significant change in traffic is supported by a p-value of 6E-124 and 5E-173 for Speed.

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