SNR-BASED DYNAMIC MANET ON DEMAND ROUTING PROTOCOL FOR VANET NETWORKS

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ABSTRACT

Vehicular ad-hoc network (VANET) is gaining the research interest lately due to its advantages in providing valid and fresh information for vehicles on the road. In VANET information exchanges between vehicles and a server in a multi-hop fashion. Multi-hop fashion implies an existence of multi route to a destination, and a routing protocol has the role of determining the best path among the exciting routes to a destination. Most of the current routing protocols use the traditional hop count as a metric to distinguish between routes. In this paper SNR is proposed as routing metric to determine the best path to a destination. Moreover, this paper focuses on development and implementation of routing protocol metric namely SNR for Dynamic MANET on-demand (DYMO) protocol in VANET. The new routing metric is implemented in the DYMO model in INET module under OMNET++ simulator. A simulations study has been carried out to analyze the performances of the improved DYMO with SNR. Moreover, a comparison between the DYMO and modified DYMO is conducted to study the effect of mobility, network road traffic condition and data traffic density. Network performances have been studied in terms of throughput, end-to-end delay and Protocol overhead. The obtained result show that the modified DYMO has better performances compare to the DYMO with the traditional hop-count metric.

Key words: ad-hoc networks, DYMO, routing protocol, routing metrics, SNR, VANETs.

INTRODUCTION

Vehicular Ad-Hoc Networks (VANET's) application is directly attached to our daily life activities, which results in a high demands for a rapid development for VANETs. VANET adopts Mobile Ad-Hoc Networks (MANETs) technologies and protocols for vehicles in the road applications. Due to the similarity between VANET and MANET protocols; most of research issues in VANET are inherited from MANETs, such as nodes mobility, and high topology changes. Vehicles mobility brings a great challenge to VANET in terms of connectivity robustness. Moreover the VANET topology natures, where nodes are a line for long distances (highways) emphasis the role of routing protocol in the network performances. Furthermore, the multi-hop communication nature in VANETs brings the need for a robust routing protocol, where most of times more than one path is exists between the source and destination nodes. From the routing protocol points of view, the selection of the optimal path among multi-paths depends on the routing metric. Typically, the path obtains the best metric will be selected, and hence design a routing metrics for VANETs networks is becoming an important topics, and has gained the focus of researches in this area. Designing a routing metric for routing protocol in MANET are studied and proposed in many researches [1] [2] [3]. Never the less, a few researches considers designing a routing metric for VANETs. In the literature many researches are focused in designing a routing protocol for VANET requirements [4] [5] [6]. Moreover, in [7] a comparison between various routing protocols for VANET was carried out, however these routing protocols are mostly implemented for MANET. This research is aimed at design a routing protocol metric based-on link quality measurement in the data link layer namely Signal-to-noise ratio (SNR). Unlike traditional routing metric, the new metric has the advantage of creating no additional traffic to measure the link quality, which results in less overhead is generated by routing protocol. The new metric is also adaptable to other routing protocol, however in this paper it's only implemented in Dynamic MANET On-demand routing protocol (DYMO). The proposed metric is inspired by the fact that, while a frame is received at the network interface card NIC, the receiver measures the SNR of the incoming signal to decide either to accept the received frame or discard it according to certain threshold value. For example if the received signal below the threshold value, the receiver will consider the frame as noise and discard it. The proposed metric in this paper is making use of the SNR information by the NIC to reduce the protocol overhead of calculating a routing metric. Furthermore, this paper focuses on the design and implementation of signal-to-noise ratio (SNR) as a routing metric for DYMO routing protocol in VANETs. The SNR metric is implemented in the DYMO routing protocol and studied against several design parameters (mobility, vehicle traffic condition, and data traffic density) in a VANET scenarios, and the performances of the network are measured in terms of throughput, End-to-End delay, and protocol overhead. Lastly a comparison between DYMO with the traditional hop count metric and DYMO with SNR metric is conducted.

The rest of this paper is organized as follow, next section discusses selected literature on the research topic, followed by overview on the design of the proposed metric, and its implementation procedure. In section 3, the simulation scenarios and results are presented and discussed. Section 5 concludes the work in this paper.

SNR ROUTING METRIC

Literature review

In multi-hop communication network such as VANET, more than one path is usually exist to transfer a packet between a pair of nodes (source, destination); and the adopted routing algorithm is in titled of selecting the best path based-on a routing metric. Technically speaking, routing metric is the weight or a cost needed to transfer the data through the path such as number of hops or hop-count and delay (time induced to transfer a data through the link). Hop-count is the simplest yet implemented routing metric where each link in the path (connection between adjacent nodes) is weighted as either exist (1) or not exist (0). And the best path will be the one with minimum hop-count. For example, Figure-1 represents a weighted network graph, where circles represents nodes and solid lines represent links between nodes. Each link is weighted with its delay cost attached to it. In this example there are exists two paths (doted lines) from node S to Node D (Path 1: N2,N3, and Path 2: N5,N6,N4) in this example if the routing protocol is using hop-count as a metric path 1 costs 3 hops and path 2 costs 4 hops, accordingly path 1 will be selected as the best path. However path 2 will cost (2+3+3+1 = 9 time units) which is less than the time required by path 1 (5+9+1=16 time unit). Hop count metric is likely to be used in wired network, where links are usually stable and could be assumed to have similar quality. However in wireless networks, wireless link is effected by many factors, and as a result the assumption of link similarity is invalid for wireless network. This fact motivates many researches to propose link quality metric for routing protocols such as link delay and bandwidth.

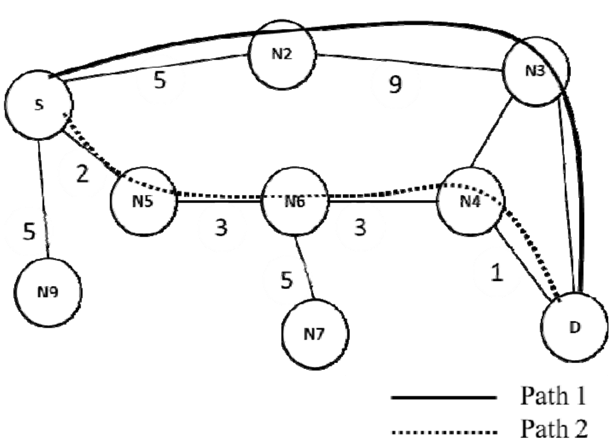

Figure-1. weighted network graph.

The problem of measure wireless link quality and use it as routing metric is taken as research topic for many researches. In [8] the Expected Transmission Count (ETX) metric is proposed. ETX uses the estimation of number of transmission required to successfully transfer a packet between pair of nodes as a metric. ETX is calculated by periodically broadcast control packet to neighbors' nodes, and ETX will be estimated based on the received PER (Packet Error Rate). This mechanism introduces additional overhead on the network. Moreover the prediction nature of ETX make it failed to achieve high performances in high topological changes network such as VANET. Many other metrics based on the ETX and PER estimation are proposed. In [9] a delay based metric is proposed (Expected Transmission Time ETT). ETT is calculated based-on ETX and transmission delay. Transmission delay is calculated according to the current transmission rate of the link, which is not reflecting the actual delay. In [10] a metric based-on the minimum packet loss (ML) is proposed. ML metric defines link cost as its Packet Error Rate PER. For further readings on routing metric readers can refer to [11] [12].

SNR design and implementation

Inspired by the fact that, SNR is measurand used to quantify wireless link quality, and its priory calculated at the receiver as indicator of the erroness and corruption induced by the wireless link. This paper proposes the use of the obtained SNR value at the reception of a frame on the MAC layer as a routing protocol metric in the network layer. To achieve this goal a cross layer design is implemented, and the overall design is achieved into two phases. The first phase is on the MAC layer, where the SNR value is obtained by the NIC. Before attaching the SNR value to the incoming frame a quantization to the SNR value will be conducted, and the quantized value will be attached to the incoming frame. The purpose of the quantization procedure is give an integer value to an SNR value, and that is because the limitation of the metric field on the routing protocol packet. Then the modified frame with the SNR value attached is passed up to the network layer. The following pseud code is describing the adhered mechanism.

```
SNR quantization algorithm

Define avg (average value)
Define std(standard deviation)
for(all received frames)
  start quantize
     get the SNR value of the received frame.
     If ((avg+2*std)<SNR)
          Q_SNR = x1
     Else If ((avg+1std)<SNR)
          Q_SNR = x2
     Else If ((avg)<SNR)
          Q_SNR = x3
     Else If ((avg std)<SNR)
          Q_SNR = x3
     Else If ((avg-2*std)<SNR)
          Q_SNR = x4
     Else
          Q_SNR = x5
          Return Q_SNR
  End quantize
  Attache Q_SNR to packet
End for
```

Figure-2. Pseudo code for SNR quantization algorithm.

The second phase takes place on the DYMO routing protocol algorithm. In the second phase, the calculation of the optimum path is modified, and the best route selection criterion is modified to use the attached SNR instead of the traditional hop count.

The idea of DYMO routing protocol develop from the concept of its predecessors Ad-hoc On-demand Distance Vector (AODV) routing protocol and Dynamic Source (DSR) routing protocol with some modification for better adept to the mobility of the nodes in ad hoc network. The main different between DYMO and AODV routing protocol is that, the routing table of the node contain information about the routes of every immediate node [13]. From the point of view of this paper, the modification to DYMO is done in two places. The first one on the reception of route discovery request, then the algorithm will select the route with the highest SNR value. The following steps are describing the route discovery procedure in the modified DYMO protocol:

```
DYMO route discovery procedure

While (packet from upper layer)
    If (no route exists to destination)
         Broadcast RREQ (with keep track of
         intermediate nodes)
    End if
    If (RREQ is received by intermediate node)
         Get the SNR value
         Re-Calculate SNR average for received route
         Update routing table
    Forward the RREQ
    End if
    If (RREQ is received by the destination)
         Get the SNR value
         Re-Calculate SNR average for received route
         Update own routing table
         Create a RREP to the source node
    End if
    If (RREP is received by intermediate node)
         Update routing table
         Forward in the backward route "RREQ
         contains all intermediate nodes in the path"
    End if
    If (RREP is received by the source node)
         Update its own routing table
         Route is established
         Send(upper layer packet)
    End if
  End while
```

Figure-3. Pseudo code for modified DYMO route discovery procedure.

The second place in the route maintenance procedure. Same as in AODV and DSR, DYMO makes use of the RERR in the link failure situation. When a link between two nodes is broken, the sender node broadcasts a RERRY message in the network. When any node receives a RERR message it updates its own routing table according to the received information on the RERR packet by removing all routes that are related to the broken link.

RESULTS AND DISCUSSION

Scenarios design parameters

The discrete event simulator OMNET++ is used to implement the proposed metric. And the DYMO routing protocol implementation in INET framework is modified by integrating the SNR metric. Three scenarios setups are design based on the design metrics namely mobility, traffic condition and data traffic density. For each design parameter a comparison between the traditional hop count and the SNR metric on DYMO protocol in terms of throughput, end-to-end delay and protocol overhead.

Throughput: Throughput presented in this paper is referring to the network throughput, which is the amount of successful data received per second. Throughput is calculated based-on equation (2).

$$Thr = \frac{\sum D_r}{T} \quad (2)$$

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D_r = Data received in bits
T = Total simulation time in seconds

End-to-End delay: end-to-end delay demonstrated in this paper is referring to the amount of time elapsed by a packet starting from its generation at the source node to the moment it received at its last destination.

Protocol overhead: is referring to all data received at the routing layer except the data that is intended to the application layer of the same node. Protocol overhead is calculated by subtracting the amount of data sent to application layer of a certain node from the data received at the routing layer of the same node. Protocol overhead includes all control traffic and forwarded data as intermediate node.

To measure the any of the performance parameters for certain design metric, 10 runs are performed for different random generation number (the random generator could be changed per simulation run in a form of seed number), and the average of the measured performances metric is presented in a graph against the design metric.

The following subsection presents the scenario parameters and the obtained results in respect to the design parameters.

Table-1. Mobility scenario simulation parameters.

Parameter	Value
Mobility module	Linear mobility
Packet size	512 Byte
Traffic generation	0.24 Mbps
Number of nodes	Mobile (3 ~ 30 nodes), Static (1~27 nodes)
Speed	16.67 m/s

Mobility

In the mobility scenario, the mobile nodes are vehicles in a highway with 10m in width and 2Km long. Mobile nodes refer to vehicles moving in a highway speed, the static node is the Road Side Units (RSUs) such as the surveillance cameras, or access points that were installed on the road side. The mobility ratio refers to the ratio between the mobile and non-mobile nodes. Typically speaking, for a scenario with 21 moving cars and 9 RSUs, the mobility ratio is 70%, which is calculated based-on equation-1.

$$\text{Mobility ratio} = 100 \times \frac{\text{Number of mobile nodes}}{\text{Number of static nodes}} \qquad (3)$$

The sum of number of dynamic mobile node and static node is set to fix number, however the number of moving cars and RSUs is changed per simulation run to achieve the desired mobility ratio. Table-1 presents the rest of the simulation parameters for mobility scenarios.

Figure-4 presents the network throughput as a function of mobility ratio for both DYMO with hop-count and DYMO with SNR scheme routing metrics. As expected DYMO with SNR scheme provide the highest degree of throughput (0.37Mbps at 100%) while for DYMO with hop-count provide the lowest levels of throughput (0.15Mbps at 100%).

Figure-5 depicts the end-to-end delay with respect to mobility ratio for DYMO with hop-count and DYMO with SNR scheme. The results show that both the DYMO with hop-count and DYMO with SNR scheme suffer increased of end-to-end delay as the mobility ratio increase(1.2 sec at 90%).

Figure-6 illustrates the protocol overhead as a function of the mobility ratio for DYMO with hop-count and DYMO with SNR scheme. Increases in mobility ratio increase the protocol overhead. The results demonstrate clearly that the DYMO with SNR scheme yields significance level of protocol overhead (1.5MB at 80%) as compare to DYMO with hop-count (2MB at 80%).

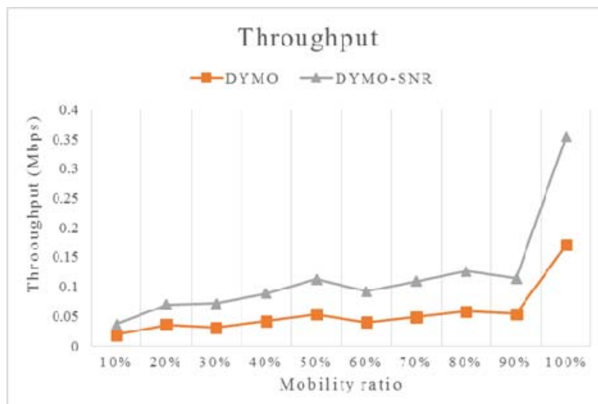

Figure-4. Throughput vs. mobility ratio for DYMO and DYMO-SNR.

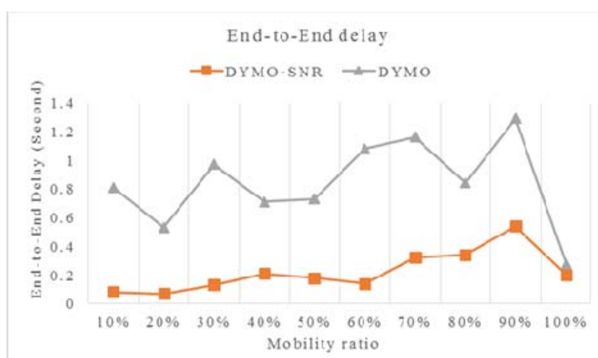

Figure-5. End-to-End delay vs. mobility ratio for DYMO and DYMO-SNR.

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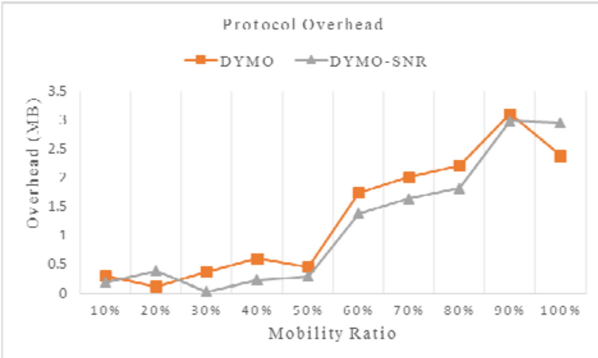

Figure-6. Protocol overhead vs. mobility ratio for DYMO and DYMO-SNR.

Traffic condition

Traffic condition or vehicle traffic condition is measured based-on number of vehicle in specific area and their speed. For example in high traffic area vehicles are condense in a small area and moved in slow speed , while low traffic "such as highways" vehicles are moving in relatively high speed and distance between vehicles is relatively longer than in high traffic areas.

Table-2. Traffic condition scenario simulation parameters.

Parameter	Value
Mobility Module	Linear Mobility
Packet size	512 Byte
Traffic generation	0.24 Mbps
Number of nodes	Mobile (23 nodes), Static (7 nodes)
Speed	22.2, 16.67, 8.33, 2.78 m/s
Distance between	(250, 100, 50, 20, 7) m

Table-2 shows the simulation parameters for traffic condition scenarios. Figure-7 depicts a network throughput comparison between DYMO hop count and DYMO-SNR with respect to the traffic condition. A slight improvement in throughtput of DYMO-SNR scheme is observed; 0.14 Mbps with DYMO-SNR scheme compared to DYMO-hop count at very low traffic condition. Figure-8 and Figure-9 present the comparison between DYMO-SNR and DYMO-Hob count considering the traffic condition as a design parameter. The comparison is conducted in terms end-to-end delay and protocol overhead. Again DYMO-SNR increases the network performances in terms of throughput, end-to-end delay and protocol overhead. Moreover, from the obtained results it's noticeable that in high traffic areas, both protocols tend to perform in more efficient way in compare to low traffic area. The adhered notice could be due to the increment in the number relay nodes (vehicles are close to each other), the short distance to destination and the low speed of vehicles.

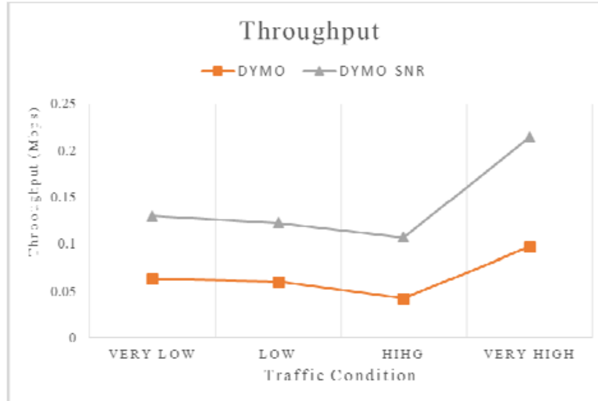

Figure-7. Throughput vs. traffic condition for DYMO and DYMO-SNR.

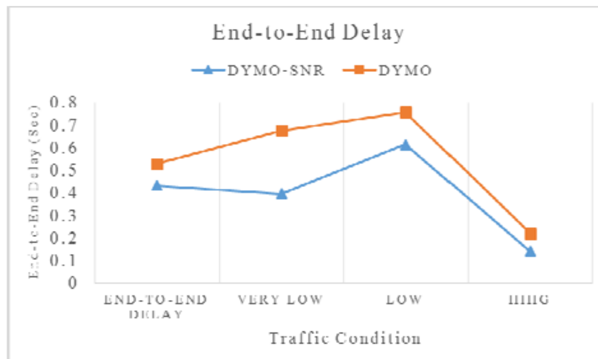

Figure-8. End-to-end delay vs. traffic condition for DYMO and DYMO-SNR.

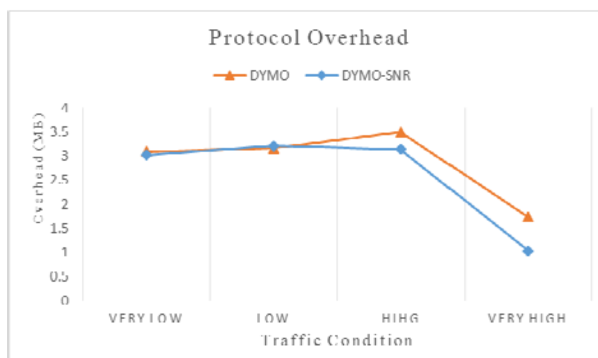

Figure-9. Protocol overhead vs. traffic condition for DYMO and DYMO-SNR.

Figures-10 to 12 presents the obtained results of the data traffic scenarios. The achieved throughput for DYMO-SNR and DYMO-hop count is demonstrated in figure-10, the obtained results shows DYMO-SNR improves the obtained throughput, and the improvement increases linearly with the increment in data traffic. Hop-count metric as one of none probing metrics, generates

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zero protocol overhead; which is the same as in SNR metric. For the adhered reason the protocol overhead results, show that both SNR and hop-count results in same amount of protocol overhead. Further, the delay for DYMO-SNR is increased for traffic generation higher than 0.5MB/s.

Data traffic density

Data traffic density is the amount of data traffic generated by either vehicles or RSU. In this paper the traffic is generated with user datagram protocol (UDP) module, where all nodes are to generate periodic traffic intended to a specific server. Data traffic density is measured in terms of amount of data generated by all nodes in second. Table-3 shows the simulation parameters for this scenarios.

Table-3. Data traffic density scenario simulation parameters.

Parameter	Value
Mobility module	Linear mobility
Packet size	512 Byte
Traffic generation	0.24 Mbps
Number of nodes	Mobile (23 nodes), Static (7 nodes)
Speed	22.2, 16.67, 8.33, 2.78 m/s
Distance between	(250, 100, 50, 20, 7) m

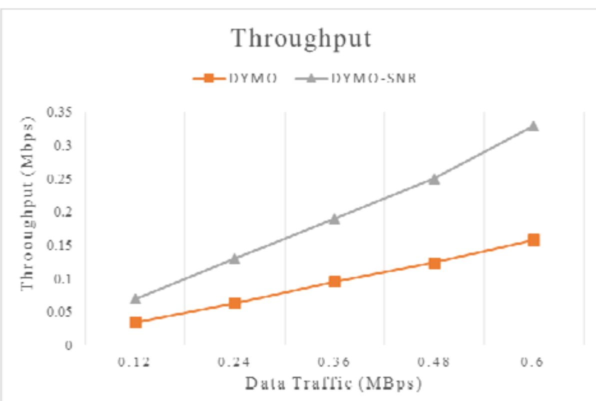

Figure-10. Throughput vs. data traffic density for DYMO and DYMO-SNR.

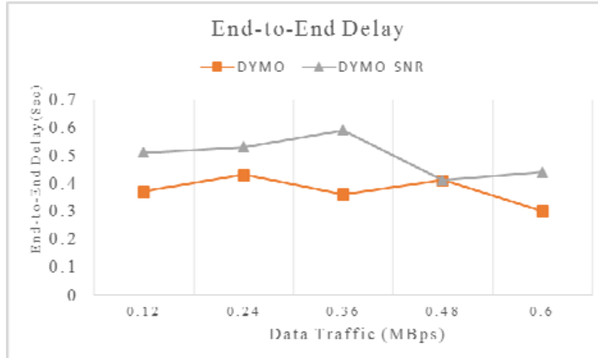

Figure-11. End-to-End delay vs. data traffic density for DYMO and DYMO-SNR.

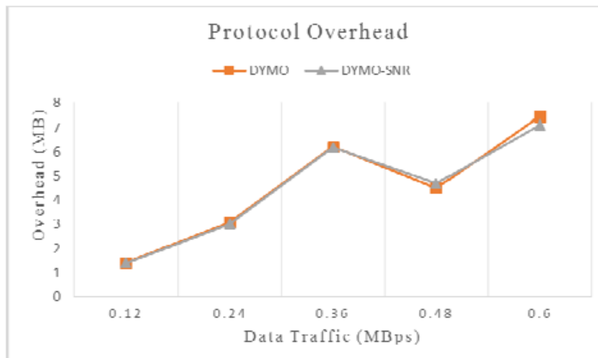

Figure-12. Protocol overhead vs. data traffic density for DYMO and DYMO-SNR.

CONCLUSIONS

This paper is considering the implementation of SNR measurement as a routing metric for DYMO routing protocol. The advantages of SNR over other metrics is its direct measure of wireless link quality and its availability on the MAC layer, where there is no need for additional propping packets by the routing protocol. The SNR obtained at the MAC layer is quantized to fit the limitation of the routing metric space on the DYMO header. Further the quantized value of SNR is adopted to both DYMO route request and route reply procedures. SNR as a metric is compared to traditional hop count for three scenarios to measure the effect of different design parameters on network performances. Obtained results shows how SNR improves the network performances in terms of throughput, end-to-end delay and protocol overhead. Even though protocol overhead is not affected in the traffic density scenarios, and slide delay cost is added, but stile SNR increases the network throughput for all traffic density conditions considered in this research paper.

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