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On The Performance of Expected Transmission Count (ETX) Metric In Flying Ad-Hoc Network.

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ABSTRACT

Flying Ad Hoc Network (FANET) is an innovative wireless communication framework that consist of the autonomous movement of Unmanned Aerial Vehicle (UAV) systems and allows communicate among them. A FANET offers an effective real-time communication solution for several applications such as commercial and civilian by treating each UAV as a router, which allow packets to be forward and receive. In contrast to Mobile Ad Hoc Networks (MANETs) and Vehicular Ad Hoc Networks (VANETs), FANETs, have a high speed mobility, irregular connectivity, and rapid changes in topology, which provide significant issues in the formulation of routing metrics. The Expected Transmission Count (ETX) is a routing metric designed to identify high-throughput pathways in multi-hop wireless networks. This study examines the effectiveness of the ETX metric in FANET, building on prior research that evaluated ETX across various multi-hop networks, including wireless mesh networks, to determine its viability as a primary routing metric or the need for enhancements. We use the NS-3 simulator to integrate the ETX metric with the Ad-hoc On-Demand Distance Vector (AODV) routing protocol. We have made simulation studies across several network sizes. The acquired data are compared with acquired data are compared of the hop count metric to assess its efficacy in the performance of FANETs. We use end-to-end delay, packet delivery ratio (PDR), useful traffic ratio (UTR), throughput, and jitter as keys performance metrics. The findings indicate that ETX outperforms hop count for PDR, UTR, and throughput, however, ETX exhibits an increased in delay and jitter relative to hop count. The results show that ETX may greatly improve the efficiency of routing in FANETs. This indicates that it may be a crucial factor in evolving new routing protocols for next-generation FANETs.

دراسة أداء مقياس عدد الإرسال المتوقع (ETX) في شبكات الادهوك اللاسلكية الجوية.

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الكلمات المفتاحية:
بروتوكول توجيه المسافات المتجهة عند الطلب
شبكات الادهوك اللاسلكية الجوية
مقياس عدد القفزات
مقياس عدد الإرسال المتوقع
محاكي الشبكات.

الملخص

شبكات الادهوك اللاسلكية الجوية هي إطار مبتكر للاتصالات اللاسلكية وتتكون من مجموعة المركبات الجوية بدون طيار,بحيث تسمح بتبادل البيانات فيمابينها.حيث تقدم هده الشبكة حلاً فعالاً لتبادل المعلومات لعدة تطبيقات مثل الأغراض التجارية والمدنية والعسكرية، حيث تعتبر كل مركبة جوية كجهاز توجيه، مما يسمح بإرسال واستقبال البيانات مع بعضهم البعض. على عكس الشبكات المتنقلة المؤقتة والشبكات المؤقتة للمركبات ،وعلي الرغم من ذلك تواجه الشبكات المؤقتة الطائرة تحديات كبيرة بسبب السرعة العالية للطائرات ، والاتصال غير المنتظم، والتغيرات السريعة في طوبولوجية الشبكات، هده العوامل تشكل تحديا كبيرا في تصميم مقاييس التوجيه الخاصة به. مقياس عدد الإرسال المتوقع هو مقياس توجيه مصمم لتحديد المسارات ذات الإنتاجية العالية في الشبكات اللاسلكية متعددة القفزات. في هده الورقة تم اختبار أداء وكفاءة مقياس عدد الإرسال المتوقع (ETX) مع بروتوكولات التوجيه في شبكات الادهوك اللاسلكية الجوية حيث ان الهدف من هدا البحث،هو تحديد مدى ملاءمته كمقياس توجيه رئيسي أو يحتاج الي تحسينات اكثر. حيث تم استخدام محاكي NS-3

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لدمج مقياس ETX مع بروتوكول توجيه المسافات المتجهة عند الطلب (AODV),وقد قمنا بدراسة تاثير التغير في عدد المركبات الجوية علي اداء المقياس ETX. و تم قياس كلا من زمن التاخير ومغدل تسليم الحزم و نسبة الحركة المفيدة والانتاجيةو والتذبدب. ومقارنة النتائج المتحصل عليها مع نتائج مقياس عدد القفزات لتقييم فعاليتها في أداء الشبكات الجوية المتنقلة ومن خلال النتائج اتضح لنا أن مقياس ETX يتفوق على مقياس عدد القفزات من حيث معدل تسليم الحزم و نسبة الحركة المفيدة والانتاجية ، ومع ذلك، يظهر ETX زيادة في زمن التأخير والتذبدب مقارنة بمقياس عدد القفزات ومن خلال هذه النتائج يتضح لنا أن مقياس عدد الارسال المتوقع يحتاج الي تطوير وتحسين وبالتالي يساهم في تطوير بروتوكولات توجيه الجديدة للجيل القادم من شبكات الادهوك اللاسلكية الجوية

1. Introduction

Flying Ad Hoc Networks (FANETs) have adopted the valuable characteristics of ad-hoc networks and traditional wireless networks. It helps to increase the capacity and coverage area and provides high connectivity to end users in a pervasive manner [1]. FANETs are self-organization, multi-hop, and self-healing, formed by autonomous Unmanned Aerial Vehicles (UAVs), where small UAVs can communicate with each other without external control. FANETs, a unique type of ad hoc network, integrate the characteristics of both MANETs and VANETs while incorporating new capabilities to meet the specific requirements of three-dimensional mobility and aerial applications. Small UAVs may function in drone swarms, whilst large UAVs may fly independently for missions. Figure 1 has shown the architecture of Flying Ad-hoc Networks (FANETs). Unmanned Aerial Vehicle (UAV) networks, in contrast to other wireless networks, have a dynamic structure that has a changing number of UAVs, connections, and locations. Depending on their specific function, unmanned aerial vehicles (UAVs) can move at varying speeds. Despite this, we need to surmount several formidable obstacles to enhance networking and communications [2]. The FANET nodes, have unique mobility, capable of reaching speeds between 50 and 560 km/h in three dimensional space.Therefore, the communication paths between UAVs exhibit significant changeability and are very unreliable. Furthermore, frequent topology changes result in high number of packet loss, routing cost, and communication delays.

The combination of high velocity, significant separation between airborne nodes, unpredictable climatic conditions, and potential failures of the nodes may lead to the disruption of links.

In such cases, it becomes necessary to construct a new routing route. Topology changes may also be caused by other events, such as mission updates. Furthermore, many military and emergency rescue applications need the consideration of low latency, high dependability, and resilience.

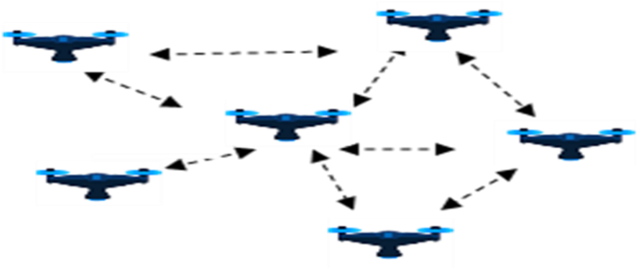

Fig. 1. Flight ad-hoc network.

In conclusion, a FANET is distinguished by its dynamic nature and frequent operations, making the development of effective routing protocols somewhat demanding. Routing is a challenging problem in FANETs. A good routing solution should be fast adaptable for any change in topology as well as in changing of wireless link condition, which often happens in FANETS. Currently, researchers are primarily concerned with developing routing protocols in the dynamic environment of FANET to increase coverage area and optimize several network factors such as delay, throughput, and overall performance. Efficient routing protocols and metrics are necessary for preserving the network architecture and finding the best routes in FANETs. Initially, Traditional MANET routing protocols are employed and evaluated for their suitability in FANET. These protocols may be categorized into four primary groups like Static protocols, Proactive protocols, Reactive Protocols and Hybrid Protocols [3]. Many popular router protocols use hop count as the default routing metric, but this metric frequently fails to select the most efficient route between the source and destination. This problem is obvious in FANET because the quality of the chosen route changes over time, so an increase in the number of link breaks will cause significant packet losses [3]. The Expected Transmission Count (ETX) metric [4], is based on both link quality and transmission probability, is more effective than the hop metric. The protocol uses two broadcasting packets, one during route discovery and another is periodic broadcast, which continuously measures the loss rate for each link. It uses the loss rate of a route's links to predict how many total transmissions and retransmissions would be required to deliver a packet along the route. A route from source to destination is being selected based on total minimum loss rate. Despite its potential to enhance network performance through highly reliable route selection, FANETs have not extensively explored this metric. In this paper, we simulate ETX metric to study its impact on the performance of the FANET routing protocol. Further, we have also conducted a comprehensive analysis to determine if the ETX metric can be efficient or requires improvement to enhance the performance of the AODV when it is employed as a routing protocol in FANETs. The reminder of this article is organized as follows, related work has been discussed in section II, the Simulation environment used in this study, including network topology, traffic patterns and simulation parameters in section III. Section 4, presents results and discussion and Finally, Section IV concludes the paper.

2. Related Work

The routing protocols in FANETs are a very broad topic, such that many existing studies have been done for the development of the routing algorithms [5] in recent years. These studies include static, reactive, and proactive routing protocols [6] and [7].

Even though AODV was proposed back in 1999 [8], it is still one of the most used routing protocols. Several research efforts have focused on analysing the use of the AODV protocol in various types of MANETs, like in [9].

Additional study results demonstrate that the AODV protocol can also be used in different wireless networks, such as wireless sensor networks. In [10], a ZigBee AODV (Z-AODV) has been proposed to make the AODV protocol suitable for wireless sensor networks, while in [11], [13], the modifications of the AODV have been made to work with better QoS in VANET. To improve the route discovery and route maintenance mechanisms in the multi-hop routing protocol rather than hop-count, the ETX metric [3] has been introduced into route cost. It is based on the number of sent probe packets and received packets.

ETX metric can also be employed for specific VANET routing protocols; for example, the Link State-Aware Geographic Opportunistic (LSGO) [14] routing metric combines geographic location with ETX. The hybrid metric has been included in [15]. With collision-aware routing (SCAOR) for VANET, the metric comprises three parameters: node density, link quality based on ETX, and packet advancement.

3. Simulation Environment

3.1 Simulation Parameters and Topology

We have examined the behaviour of ETX and hop count metrics using the network simulator NS-3.33[16]. We incorporate the AODV routing protocol with ETX metric and simulate AODV in both case one in case of using ETX with AODV (AODV-ETX) and other in case of use AODV with hop count (original AODV).

Table 1 provides all simulation parameters used in this simulation environment, while Figure 2 illustrates the simulation topology.

TABLE 1: SIMULATION PARAMETERS

Parameters	Values
Application Type	Constant bit rate (CBR).
Number of UAV sources that transmit packets.	20
Routing Protocols	AODV-ETX, AODV-hop count
Simulation time	110 seconds.
Packet Size	64 bytes.
Data rate	2048bps.
Simulation area	2000m × 2000m ×900m.
Transmission power	20dbm.
Physical data rate	6Mbps.
Modulation type	OFDM and 10 MHz bandwidth.
Mobility Model	Gauss Markov Mobility Model [12].
Speed Mobility	[0-60]m/s.
Mobility model.	Random way point.
MAC layer.	802.11p
Antenna model.	Omni Antenna.
Propagation model.	Two Ray Ground Propagation Loss Model.

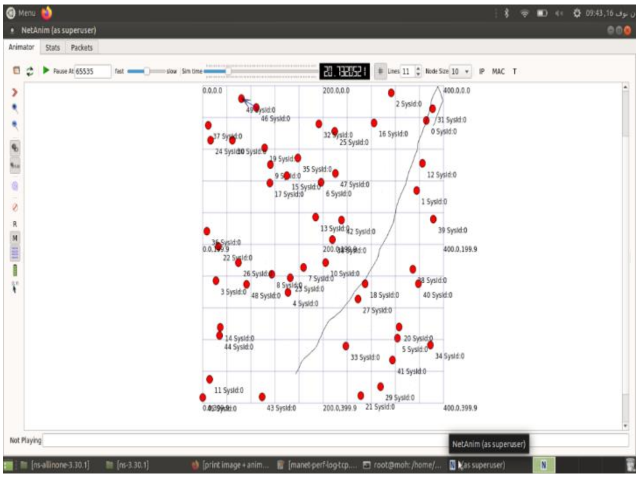

Fig. 2. .Simulation Topology.

3.2 Performance Metrics

In this section, we introduce the following metrics of interest to evaluate the performance of the ETX and hop count metrics described in this work.

3.2.1 Average Throughput: is the number of data packets in bits that have received at destination during exchange a data packets between UAVs, we can expressed as:-.

$$\text{Average Throughput [b/s]} = \frac{P_r * 8}{T_r - T_s} \qquad (1)$$

Where, T_r the time at which last packet is received by receiver and T_s is the time when the first packet has sent by sender, Where Pr is the total number of received successfully packets in bytes.

3.2.2 **Average End To End Delay (AEED):-** it is a total time taken by all data packets from source to destination over total number of successful received data packets, we can expressed as:-.

$$\text{AEED=End\_to\_End\_delay} \times 1000\text{(ms)}. \qquad (2)$$

Where

$$\text{End\_to\_End\_delay} = \frac{TDT}{\sum_{i=1}^{N} P_r} \qquad (3)$$

$$\text{TDT=TDT} + \sum_{i=0}^{N} delay\,[i] \qquad (4)$$

$$\text{delay[i]} = T_r[i] - T_s[i]. \qquad (5)$$

Where P_r represents a total number of successful received data packet, delay[i] is delay of flow i.

3.2.3 **Packet delivery ratio (PDR):-**

It is a ratio between a number of received data packets by destinations UAVs to total number of data packets that sent by UAVs senders, we can expressed as:-.

$$PDR = \frac{\textit{Total number of recieved data packets}}{\textit{Total number of sent data packets}} \; X\ 100 \ (6)$$

3.2.4 **Jitter: -**

It is the delay variation between subsequence received data packets.

3.2.5 **USEFUL TRAFFIC RATIO (UTR)** :

It is the ratio between total number of received data packets in bytes to total number of sent control packets and sent data packets, we can expressed as :-

$$UTR = \frac{Totalnumberofrecieveddatapackets}{totalnumberofsentpackets} \; X\ 100 \ (7)$$

4. Results and Discussion

We have conducted simulation experiments with varying numbers of UAVs. The simulation results of the ETX metric have been compared with the simulation results of the hop count metric. Using a simulation model described in previous sections, end-to-end delay, throughput, packet delivery ratio, and useful traffic ratio have been determined and plotted. The performance metrics are obtained by averaging results over 100 simulation runs. Each data point represents an average of at least 10 runs with identical traffic models but randomly generated different mobility scenarios. Identical mobility and traffic scenarios are used throughout our work.

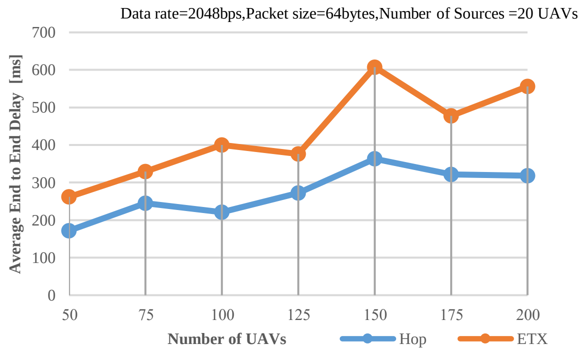

Fig. 3. Average End to End delay (ms). Vs. Number of UAVs.

We study the impact of network density on network performance by varying the number of UAVs in terms of jitter and average end to end delay. From figures 3 and 4, we can observe that as the number of UAVs increases, both end-to-end delay and jitter increase for both the ETX metric and the hop count metric. We noticed that the delay in ETX metric is larger than the hop count metric. This is due to fact the ETX metric takes time to calculate the link quality for each link from source to destination, hence, the route establishment takes more time than hop count metric. Furthermore the path length of the ETX metric might be is longer than the path with hop count metric.

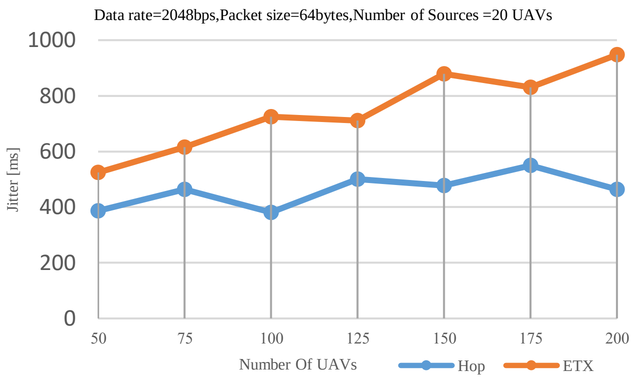

Fig. 4. Jitter .vs. Number of UAVs

It can be seen from figures 5 and 6, that throughput and PDR (packet delivery ratio) are inversely proportional with an increase in the number of UAVs, This is because the number of packets that are received at destinations decreases as the number of UAVs increases. We can observe that the ETX metric consistently performs better than the hop count metric across various numbers of UAVs, this helps in sustaining better throughput and packet delivery ratio in dynamic and dense network environments.

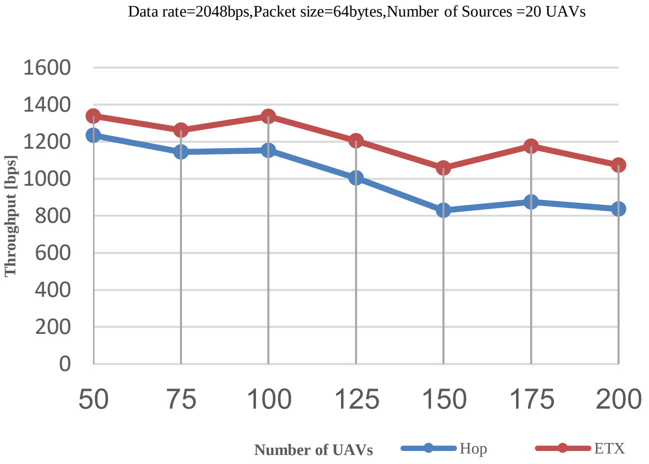

Fig5. Throughput. vs. Number of UAVs

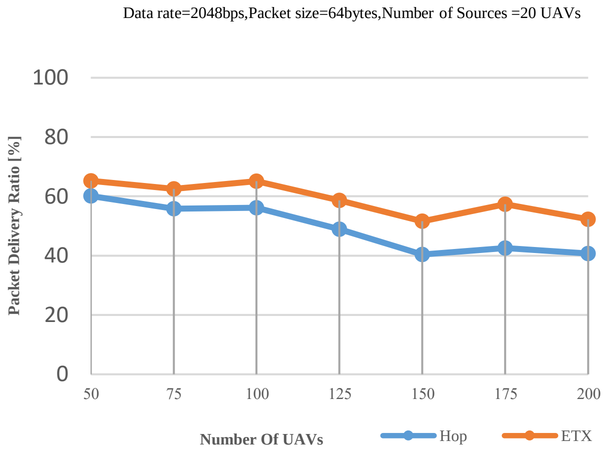

Fig6. Packet Delivery Ratio. vs. Number of UAVs.

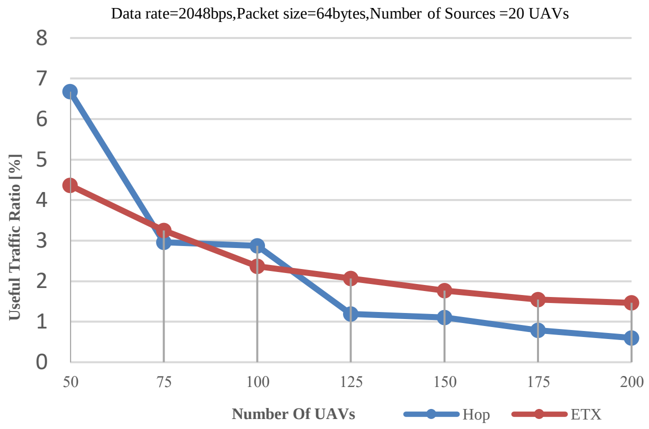

Fig7. UTR .vs. Number of UAVs.

From Figure 7, we can observe that regardless of whether ETX or hop count is used, routing protocols present a Useful Traffic ratio (UTR) that decreases with an increase in the number of UAVs. Where in a small number of UAVs, the ETX metric has a lesser UTR than ETX, while in a high number of UAVs, the hop count metric has a lesser UTR than ETX metric. From these results, we can conclude that, the hop count, unable to bear efficiency in large networks, while the ETX has better performance in large networks.

5. Conclusion

Flying Ad Hoc Networks (FANETs) comprise autonomous UAVs that communicate autonomously, independent of external network infrastructure. In this paper, we simulate the ETX metric against a traditional hop count metric, the proposed work has focused on evaluating the ETX metric in terms of effectiveness and efficiency in dynamic network environments such as FANETs. The simulation results under different numbers of UAVs, show us that, the ETX metric has a higher delay and jitter compared with the hop count metric and a better packet delivery ratio, Useful Traffic Ratio and throughput however, the ETX metric needs to be modified for working better in FANETs, A forthcoming study may focus on optimizing the ETX metric to minimize delay and jitter, hence enhancing its efficacy for routing protocols. Subsequent investigations ought to concentrate on enhancing ETX for real time applications. Figuring out the impact of environmental parameters, such as mobility models, on ETX could facilitate the development of adaptive algorithms for FANETs.

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