Analyzing and Optimizing of Quality of Service Management in Flying Ad hoc Networks

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Abstract—*The rapid advancement of wireless communicationslead to the emerging new technology of ad hoc connectivity by the Dynamic Distributed Flying Ad hoc Networks (FANETs) which are equipped with flying nodes like Unmanned Aerial Vehicles (UAVs). Due to the dynamic topology nature of wireless links and the high mobility of the flying nodes, the traditional wired quality of service (QoS) routing protocols as well as existing Ad hoc network protocols could not be easily compatible with the Flying Ad hoc networks. Hence there were challenges of QoS provisioning and management mechanisms in the operation and implementation of FANETs. This paper was discussed several approaches of the QoS provisioning solutions that have to be employed with in the FANETs. However, entirely it was defined the layer-wise QoS solution approaches in detail. It was discussed the network layer and MAC layer QoS solutions where the QoS routing protocols of those respective layers included in this manuscript.*

For a verified proposed solution the study was equipped with some simulations which were demonstrated using the OMNET++ ((Objective Modular Network Test bed in C++) network simulator. Three protocols of network layer QoS solution such as Predictive Location-based QoS routing (PLBQR), Trigger-based Distributed QoS routing and QoS enabled ad hoc on-demand distance vector routing (QOSAODV) were simulated. It was found that PLBQR have shown better QoS provisioning performance among those three QoS routing protocols. Other simulation scenario also carried out with the MAC layer QoS routing protocols such as Multiple Access Collision Avoidance with piggy-backed reservation (MACA/PR), Real-Time Medium Access Control Protocol (RTMAC) and Distributed Bandwidth Allocation/Sharing/Extension (DBASE). Among the MAC layer QoS routing protocols discussed here, it was verified that DBASE had an efficient overall QoS routing capability than others.

Index Terms—**Unmanned aerial vehicles, Quality of service,Quality management.**

I. INTRODUCTION

Few decades ago the maximal involvements of electromechanical microchip devices had contributed a great outcome to the mobile computing and distributed systems integration. Portable equipment has increased to attract the attentions of customers and Enterprise systemowners. Hence, human beings devoted to use and interact such portable and zero-configuration technologies for the simplicity of their day to day activities and to save resource wastage. One of these which are easily operable technologies is Wireless Ad hoc network. Flying Ad hoc

Network (FANET) is one of the current attractive and impressive Ad hoc network classes which operate on the Aerospace.

This manuscript had been focused to state and distinguish with FANET issues related to quality of service (QoS). It was common that several questions were raised from the scientific society about the service guarantees and operations of UAVs which work based on the FANETs since UAVs are very attractive outcomes of this century technologies. However, no more studies and experiments were done about the service delivery guarantee with in FANETs. It was known that many open research issues with respect to the QoS of the FANETs had not been addressed.

The requirements of users to satisfy their specified portion of service during the transmission of the packets from the source to the destination was termed us the Quality of Service (QoS). In other words the QoS is the possibility of delivering the packets requested by user along the Source-Destination path. Networks should have to obey the predefined attributes of service so that performance metrics such as delay, bandwidth, probability of packet loss, delay variance (jitter), power consumption etc. [55, 56] guaranteed in a measurable scheme.

Within UAVs the communication using FANETs transmits several types of applications which were being carried out different types of data, which include GPS locations, streaming video/voice, images, simple text messages, etc. It was an issue that FANETs should support good quality with less delays and error rates to satisfy a set of predetermined service performance metrics.

Defining a comprehensive frame work for QoS enabled middleware is a crucial challenge due to the highly mobile and dynamic structure of nodes within the system. There was a research gap on implementing QoS models and providing QoS mechanism with in FANETs. Thus, this manuscript was demonstrated to accomplish activities such as reviewing of existing QoS schemes/architectures, enhancing of existing QoS architectures, analysis of QoS routing protocols, compare the QoS routing protocols and validate the proposed solutions for the optimization of QoS in FANETs.

II. SUMMARY

FANETs refer to self-organizing networks, where the operating nodes of the network are flying Unmanned Air Vehicles (UAV). Though many purposes and benefits were admitted by FANETs, there are many challenges on the reliability and related issues of such networks that include routing, security, QoS provisioning and other problems [18].

A. QoS within FANETs

In the wired networks QoS solutions such as IntServ (Integrated Services) and DiffServ (Differentiated Services) were existed and ultimately used. In wireless networks, most of the time, tasks have been done towards enhancing the general performance provided by the network rather than offering service differentiation according to applications or user requirements.

In most of the traditional ad hoc networks such as MANET there are some notable QoS models and mechanisms which are FQMM, iMAQ, 2LQoS, INSIGNIA and SWAN. FQMM which stands for Flexible QoS Model for MANETs was the hybrid QoS provisioning policy combining both DiffServ and IntServ in which traffic is divided into classes or flows. IMAQ which mean Integrated MANET QoS was cross-layer architecture for multimedia traffics. 2LQoS (Two-Layer QoS) is a model which separates QoS metrics according to the layers (Application, Network and MAC) [57, 58, 59].

INSIGNIA, the "In-band Signalling Support for QoS In Mobile Ad hoc Networks" was the framework based on signalling designed for MANETs to support QoS: - it is based on In-Band Signalling [60]. The INSIGNIA QoS model adds set of option headers to the IP packets of the data transmission for resource reservation signalling. In collaboration with the admission control mechanism INSIGNIA can support for providing the QoS for real-time traffic networks. Having the added header options of each IP packet headers within each packet the overall resources between source-destination pairs can be allocated, reallocated, managed, restored and reserved [61].

SWAN is another QoS model approach of framework which was known as the "Service Differentiation in Stateless Wireless Ad hoc Network", that is a stateless QoS model with distributed approach proposed to provide QoS for wireless ad-hoc networks. The SWAN model supports the two classes of network traffics such as the real-time traffic and best-effort traffic. SWAN uses different control mechanisms for those two classes of network traffics, for best-effort it uses rate control and for the real-time traffic it uses sender-based admission control. Having considered availability of bandwidth within the source to destination network traffic in SWAN the admission control should have to be approved [62].

Since a FANET was a new emerging area of study among the wireless Ad hoc networks there was no study orexperiment which has demonstrated FANET-specific QoS models and mechanisms. QoS models that have discussed in early studies such as in [57] were emphasizing mostly in Mobile Ad hoc networks (MANETs) and wireless sensor networks (WSN). No more literatures show suitable QoS frameworks and models for FANETs among the stated QoS models. When the issues of QoS in FANETs were concerned routing is one of the challenging problems for ensuring QoS provisioning. Existing routing protocols for ad-hoc networks are showing a limitation in the case of QoS [18].

B. QoS Routing Protocols

The QoS solutions for FANETs can be stated based on the interaction of different layers and frameworks. It was discussed that the MAC layer and Network layer protocols are mandatory for the efficiency of FANET services throughout the system. The following QoS routing protocols have been discussed within this paper.

i. Multiple Access Collision Avoidance with Piggyback Reservation (MACA/PR).

MACA/PR is a MAC layer protocol which was used to provide rapid and reliable guaranteed bandwidth support for the real-time traffic and non-real-time datagrams [74, 75]. It consists of main components such as MAC protocol (MACAW with non-persistent CSMA), reservation protocol, and QoS routing protocol.

MACA/PR provides a non-real-time datagram transmission in which hosts sending the packets have to wait for a free window in the reservation table (RT). Reservation table (RT) is the tool used in MACA/PR protocol for storing all the records of send and receive window on the transmission range. The protocol use packet dialogue of Request-To-Send (RTS)-Clear To Send (CTS)-Data Packet (PKT/DATA)-Acknowledgement (ACK) for the successful transmission of the packet [74].

In the transmission of real-time traffic, the transmission mechanism was different from the non-real-time transmission. In the real-time connection the send initiates the RTS-CTS dialogue followed by the PKT-ACK dialogue when the CTS were received. In the reservation of bandwidth in the real-time transmission, real-time scheduling information was added in the PKTs and ACKs headers. Sender can piggyback reservation information for its next transmission having the current PKT. The receiver stores the reservation in its reservation table (RT) and it confirms the sender with the ACK [74]. In general, the RTS and CTS handshakes (RTS/CTS) were used to specify the length of data packet. Stations near to the sender hearing RTS will differ long enough then sender can receive returning CTS.

ii. Real-Time Medium Access Control Protocol (RTMAC)

Real-Time Medium Access Control Protocol is an extension of DSDV protocol. It satisfies the end-to-end QoS bandwidth requirement by finding better path. It reserves bandwidth by dividing the transmission time into successive super frames. Each super-frame consists of asequence of reservation slots (resv-slots). Time duration of a resv-slot is twice of the maximum propagation delay. For transmitting real-time packets, each node reserves block of resv-slots, which is commonly known as connection-slot. It uses same connection slot for transmitting successive super-frames.

Different set of control packets have use in RTMAC protocol such as ResvRTS, ResvCTS, and ResvACK which are dedicated for the effective bandwidth reservation of real-time packets. It uses RTS, CTS and ACK for transmission of best effort packets. RTMAC prioritizes the real-time messages by using reduced interval of Distributed Coordination Function Inter Frame Space (DIFS).

iii. *Distributed Bandwidth Allocation/Sharing/Extension(DBASE)Protocol*

DBASE is an asynchronous MAC layer protocol which supports multimedia traffic of both constant bit rate (CBR) and variable bit rate (VBR). In wireless ad hoc networks there was no fixed access point to coordinate the activity of individual station. Station is nothing but like operating nodes or Ad hoc devices. A station with real-time traffic is denoted as rt-station and station with non-real-time traffic is denoted as nrt-station. The channel of Flying Ad hoc network is a broadcast channel in a distributed manner [76].

Based on the different inter-frame spaces (IFSs), DBASE protocol divides the frames in the wireless station into three priority classes such as short IFS (SIFS), priority IFS (PIFS) and DCF IFS (DIFS) [76].The SIFS is always with high priority of CTS and ACK. PIFS is used by the rt-frames with request to send (RTS) and reservation frame (RF) of video/voice packets in DBASE protocol. DIFS is used by the nrt-frames and is longest IFS with lowest priority [76].

iv. Predictive Location Based QoS Routing Protocol (PLBQR)

PLBQR is a network layer QoS routing protocol which considers the entire locations of the operating nodes (UAVs) within FANETs. This protocol overcomes the problems that arise in relation to routing information based on the locational state [75].

Though there was a QoS guaranteed admission control, there is no reservation of resources along with the path from source to destination. PLBQR takes an advantage of help for the update of node location and prediction information about delay. It also helps that each node of the system by broadcasting node’s geographical location for neighbor nodes. PLBQR constitutes two types of update messages named as Type 1 update and Type 2 update. A Type 1 update message was a message which could be generated periodically by each node. A type 2 update message was a message which has to be generated up on the considered change of topological location, node’s velocity and node’s direction [75].

v. Trigger Based Distributed QoS Routing Protocol (TDR)

TDR was a QoS routing protocol which is proposed to support real-time applications through the Flying Ad hoc networks (FANETs). This protocol considers the active routes for reducing the computational and control overheads. Local neighborhood information should be up-to-dated and maintained by each node of the system. Every node for each neighbor should maintain the attributes such as velocity of the node, direction, receive power level and current geographical coordinate locations. Having got aware of such information about the destination node the source node should perform a route discovery by reducing control overhead through selective forwarding [73].

vi. QoS Enabled Ad-hoc On demand Distance Vector Routing Protocol (QOSAODV)

QOSAODV is QoS routing protocol which was an extension of the basic ad hoc on-demand distance vector (AODV) routing protocol modified to provide QoS along with Ondemand routing. A packet format modification have been done which specifies for the service requirement of nodes that use RREQ (rout request) or route reply (RREP) [73].

The routing table of the basic AODV protocol has modified entirely to support the QoS routing features along with the existing routing table entries. A single routing table entry can be corresponding to each different destination. The fields that have to be appended to each of routing table entry are the maximum measure of end-to-end delay, the minimum average amount of available bandwidth, the number of sources list which are requesting guaranteed delay, and number of sources list requesting a guaranteed bandwidth [74].

C.Methods

The paper is based on the open issues pointed out on reviewing literature papers. It consists of three stages: formulating a problem statement analysis, experiments and simulation approaches, and simulation result analysis. The formulations of the problem statement analyses have been described on the introduction section by the series of discussions to target the goals for this paper.

In the experimental derived information phase, the problems have been evaluated by simulations. The reasons for using simulations were to illustrate the efficient routing protocols of FANETs which supports for the ensuring of QoS optimization and to verify the features QoS management with all the challenges FANET system it offers. It is not easy to define scenarios of QoS management to see both direct and indirect effects on the total performances of FANET. Thus it needs practical lab demonstrations. The simulation of all experimental activities can be done by using OMNET++ with C++ compiler.

In the final stage, the simulation result has been analyzed. The analysis process consists of different kinds of testing, tracing, and feasibility testing of the results. Analyzing and testing small system components and fractions of code before the parts are combined, and tracing single packets through the protocol layers and network, have given valuable information on the behavior and performances of FANET protocols with respect to the QoS management optimization.

D.Applications of the Result

Based on the stated and discussed points, it was expected outcomes of the study like the guaranteed service provisions with highest possible bit rates of throughput for enterprise and organizations facilitating their activities through UAVs, Wireless services which need critical requirements such as mobile healthcare applications (Mobile health) related to healthcare anytime, anywhere to anyone and reliable streaming of real-time audio, video, real-time messaging and other services.

III. EXPERIMENT AND SIMULATION ANALYSIS

Simulations have done in different scenarios and on different parameters based on the following performance metrics:-**Packet Delivery Ratio:** Packet delivery ratio tells that howmany packets were sent and how many actually delivered to the destination. Packet delivery ratio= (Total number of packet received /Total number of packet sent)*100.

End to End Delay: End to End tells that the average timetaken by a packet to arrive at the destination, it also involves delay in queue and delay caused by the route discovery. End to End delay= (arrive time –send time)/ number of connections [27].

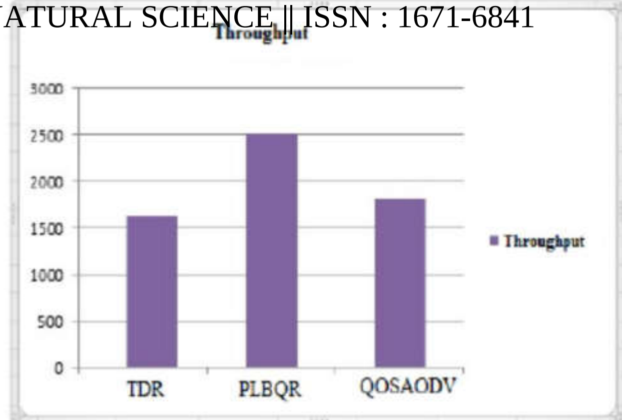
Throughput: Throughput shows the bandwidth of theprotocol.

A. Simulation Parameters

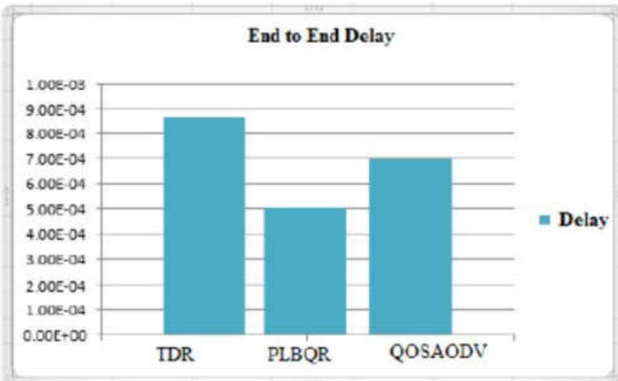
Some crucial facts demanded to verify results using simulation. In this paper some simulations have demonstrated to clarify and distinguish the efficiency of QoS routing protocols discussed above. The experimental simulation was demonstrated within two scenarios. Tables shown below are displaying simulation parameters along with sample value used during the simulation time.

TABLE 3.1: SIMULATION PARAMETERS OF SCENARIO-1

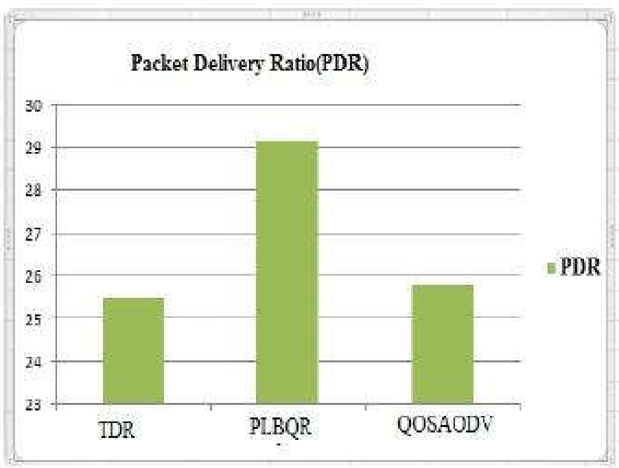
Parameter	Value
Simulator	OMNeT++ (Version 4.3)
Channel Type	Wireless Channel
QoS Routing Protocol	PLBQR, TDR and QOSAODV
Simulation Duration	900s
Number of UAVs	20
Standard Used	802.15.4
Traffic Type	CBR
Data Payload	512 bytes/packet
Max of CBR Connections	200
Node Speed	5,10,20,30,40,50 (m/sec)



(a) Average measure of Throughput



(b) Average time of Delay

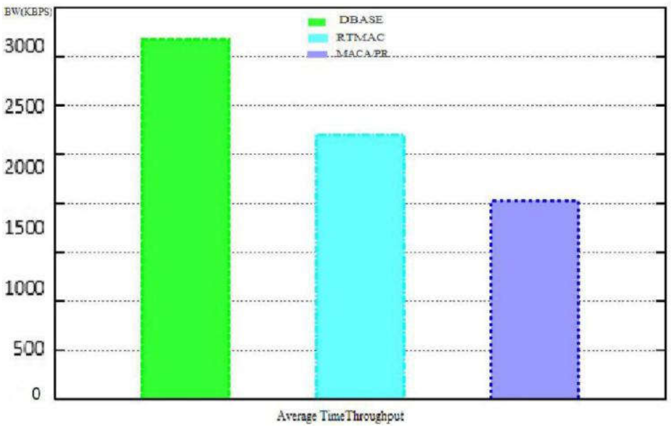


(c) PDR of the QoS routing

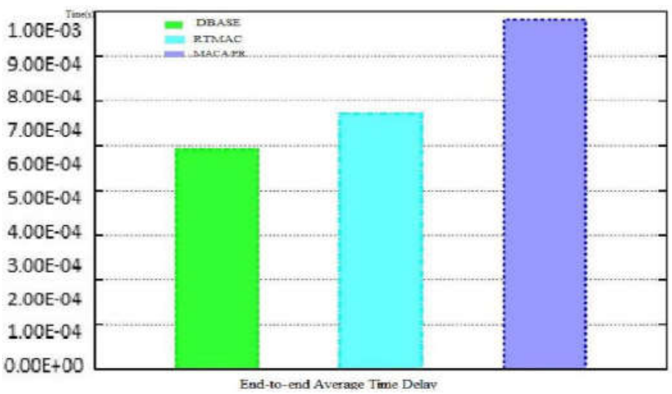
Figure 3.1: Performance analysis of QoS routing protocols PLBQR, TDR and QOSAODV

TABLE 3.2 SIMULATION PARAMETERS OF SCENARIO-2

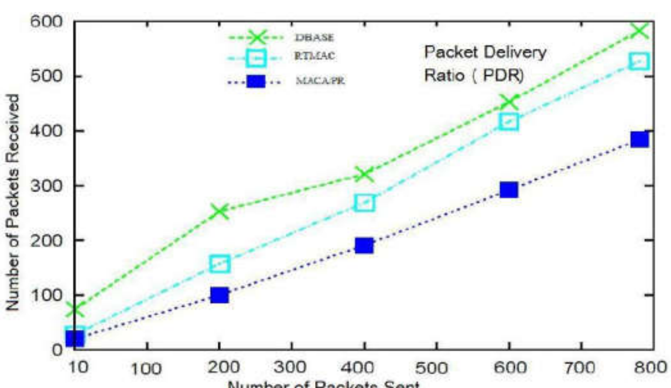
Parameter	Value
Simulator	OMNeT++ (Version 4.3)
Channel Type	Wireless Channel
QoS Routing Protocol	DBASE, RTMAC and MACA/PR
Simulation Duration	900s
Number of UAVs	20
Standard Used	802.15.4
Traffic Type	CBR/VBR
Data Payload	512 bytes/packet
Max of CBR/VBR Connections	400
Node Speed	5,10,20,30,40,50 (m/sec)



(a) Average measure of Throughput



(b) Average time of Delay



(c) PDR of the QoS routing

Fig 3.2: Performance analysis of QoS routing protocols DBASE, RTMAC and MACA/PR

B. Discussions

The outcome of simulations demonstrated in the above sub-section was basically to distinguish the performance of the selected QoS routing protocols for the optimization of the QoS provisioning and management with in FANETs. Based on the above recorded performance of the QoS routing protocols anyone can decide in providing FANETs with optimized QoS. Those protocols have tested from the three aspects: Throughput, end-to-end delay and packet delivery ratio. In the previous simulation scenarios it was evaluated the QoS guarantee efficiency of the protocols from MAC layer such as DBASE, RTMAC, MACA/PR, and also from network layer protocols like PLBQR, TDR and QOSAODV.

In the above simulation scenarios, it was recorded that DBASE protocol has robustness of QoS efficiency among the Qos routing protocols evaluated based on the provided performance metrics. Having the simulation results evaluated per each layer of QoS routing protocols, it was proved that PLBQR was efficient QoS routing protocol among the selected Network layer protocols as shown in Figure-3.1. When we look at the Figure-3.2 DBASE protocol has shown better QoS guarantee enhancement among the above simulated MAC layer QoS protocols.

IV. CONCLUSION

A lot of studies with different kinds of issues in flying Ad hoc networks have been conducted and few of them also published. But none of them have entirely concentrated within the Quality of Service problems within the system [14, 18].

In this paper, general concepts of FANETs and QoS have discussed. Several solutions proposed in the QoS provisioning for FANETs were suggested. The issues and challenges involved in providing QoS in FANETs were explained. QoS routing protocols used to optimize the Quality of Service management and provisioning have elaborately defined with their specific features. The QoS models within Wireless Ad hoc Networks were discussed briefly in general.

The paper has presented good approaches to researching on the Quality of Service management for wireless adhoc networks in general. It has provided good evidence for better performance analysis activities of the network as per layers. The QoS solutions were then discussed in a layer-wise order. Finally, simulation of some specified QoS aware routing protocols was carried out.

V. RECOMMENDATION AND FUTURE WORK

With its some obvious technical and working environment limitations, the paper expected to be good beginning as alternative for the further enhancements and improvements of the QoS in FANETs. FANET-based communication is a very important field of research. Although some research has been done in this area, much more work is still needed in order to provide reliable, trusted and secure communication in Multi-UAV systems and their applications. For example, further investigations can be conducted in order to identify, enhance, and extend existing FANET protocols to be better adapted for the Multi-UAV communication environment and its special characteristics, which were identified earlier in the paper. Furthermore, additional research can be done in order to provide better support of the various data traffic types that would use in different FANET applications. FANET based systems deployment and use in smart high technology industry is very promising.

Finally, it is better to setup prior tasks, further analysis and research is needed to provide for efficient integration of the UAV systems into the various airborne systems and civilian applications.

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