Efficient Energy Management of Unmanned Aerial Vehicle (UAV) based Flying Sensor Networks

Amul Batra
Assistant Director
Directorate General of Civil Aviation
Ministry of Civil Aviation
(E-mail: batraamul@gmail.com)

***Abstract*—** this review article analyzes Energy Management of Unmanned Aerial Vehicle (UAV) based flying sensor networks that can be improved by proficient clustering algorithms in heterogeneous wireless sensor based UAV networks. Coordination through cluster head selection provides efficient data aggregation that reduces communication overhead in the network. In this paper, we propose a fuzzy logic approach based DDEEC clustering algorithm which aims to prolong the lifetime of nodes in heterogeneous WSNs. We have compared different algorithms with the PSO based DDEEC algorithm and original DDEEC algorithm according to the parameters encapsulating a scenario in which first node dies in different rounds and energy-efficiency metrics is compared. The efficiency of old optimized fuzzy algorithm is proved by the MATLAB experimental results. Previous papers based Simulation results exhibits different algorithms having higher energy efficiency and that can improve life span of a node and data delivery at the base station.

***Keywords*—** *Unmanned Aerial Vehicle, Heterogeneous WSN; cluster head; fuzzy logic, DDEEC, Energy conservation, network lifetime.*

I. INTRODUCTION

This UAV nodes based Flying Wireless sensor network (WSN) consists of spatially distributed sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants, at different locations [1]. This network contains a large number of nodes which sense data from an impossibly inaccessible area and send their reports toward a processing center which is called ”sink”.

Since, UAV sensor nodes are power-constrained flying ad hock sensors, frequent and long-distance transmissions should be kept to minimum in order to prolong the network lifetime [2], [3]. Thus, direct communications between nodes and the base station are not encouraged. One effective approach is to divide the network into several clusters, each electing one node as its cluster head [4].

The cluster head collects data from sensors in the cluster which may be fused and transmitted to the base station. Thus, only some nodes are required to transmit data over a long distance and the rest of the nodes will need to do only short-distance transmission. Thus, more energy is saved and at the same time overall network lifetime can be increased several folds.

Many energy-efficient routing protocols are designed based on the clustering structure where cluster heads are elected periodically [5], [6]. These techniques can be extremely effective in broadcasting and data query [7], [8]. DEEC is a distributed energy-efficient clustering algorithm for the heterogeneous wireless sensor networks like UAV based flying Ad Hock sensor networks based on clustering.

When the cluster-heads are elected by a probability based on the ratio between residual energy of each node and the average energy of the network. The round number of the rotating epoch for each node is different according to its initial and residual energy. DEEC adapt the rotating epoch of each node to its energy.

The nodes with high initial and residual energy will have more chances to be the cluster-heads than the low-energy nodes. Thus DEEC can prolong the network lifetime, especially the stability period, by heterogeneous aware clustering algorithm [9]. This choice penalizes always the advanced nodes, especially when their residual energy deplete and become in the range of the normal nodes. In this situation, the advanced nodes die quickly than the others.

The DDEEC, Developed Distributed Energy-Efficient Clustering, permits to balance the cluster head selection over all network nodes following their residual energy. So, the advanced nodes are largely solicited to be selected as cluster heads for the first transmission rounds, and when their energy decrease sensibly, these nodes will have the same cluster head election probability like the normal nodes. An outline of this paper is as follows. Section II describes a review related work.

In section III, a presentation of heterogeneous network is set. Additionally, in section IV, we present the details of DDEEC algorithm. Section V gives the simulation results. Finally, conclusion is presented.

Wireless UAV equipped sensor networks composed of hundreds of sensor nodes which sense the physical environment in terms of temperature, humidity, light, sound, vibration, etc. The main task of sensor node is to gather the data and information from the sensing field and send this to the end user via base station. These sensor nodes can be deployed on many applications. Current wireless sensor network is working on the problems of low-power communication, sensing, energy storage, and computation. Clustering technique enables the sensor network to work more efficiently. It increases the energy consumption of the sensor network and hence the lifetime [1]. The main role of cluster head is to provide data communication between sensor nodes and the base station efficiently. So the cluster head should have high energy as compared to other nodes, also, it performs the data aggregation. LEACH by Heinzelman, et. al. [2] is the first hierarchical or clustering-based protocol in which cluster heads are randomly selected. Others advancements proposed for LEACH are LEACHC [3], HEED [4], SEP [5], ALEACH [6].

DEEC [7] is cluster-based algorithm in which cluster heads are selected on the basis of probability of ratio of residual energy and average energy of the network. In this algorithm, node having more energy has more chances to be a cluster head. It prolongs the lifetime of the network. In this paper our proposed scheme is TDEEC (Threshold Distributed Energy Efficient Clustering) scheme which follows the thoughts of DEEC. This scheme selects the cluster heads from the high energy nodes improving energy efficiency and lifetime of the UAV network.

II. LITERATURE REVIEW

Prashanti. S, Sang-Hwa Chung atel we have discuss the problem of congestion control over MANET. Transmission Control Protocol (TCP) is the most popular connection oriented transport layer protocol used in the current internet. However, when TCP operates in WMNs, the throughput of TCP degrades drastically due to its inability to distinguish non-congestion events such as non-congestion losses and packet reordering from network congestion. In addition, when non-congestion loss and packet reordering co-exist, the number of unnecessary retransmission increases and this will have adverse effects on TCP and its congestion control mechanism which deteriorate the performance of TCP. Several loss differentiation algorithms have been proposed for distinguishing the non-congestion events from network congestion. However, the existing schemes have no mechanism to differentiate the packet re-ordering from congestion loss. For this problem the mechanism discuss are First, the detection of packet loss due to network congestion from non-congestion losses and then packet reordering by using the modified CW scheme of TCP New-Jersey .Second, the detection of non-congestion losses from packet reordering by setting a dynamic delay threshold using the current status of the network and third, the congestion control mechanism of TCP NJ-Plus. These three features of TCP NJ-Plus helps the sender to reduce the unnecessary retransmissions and avoid needless reduction of cwnd size and thereby increase the performance of TCP over WMNs.

YassineDouga, at el presents a new approach that tries to adapt the Transmission Control Protocol (TCP) for use in Wireless ad-hoc networks (MANET). In the proposed protocol called Hybrid TCP or H-TCP, we have made some modifications using a cross layer solution to the legacy IEEE 802.11 and TCP. In H-TCP we show that we can obtain better connections on the wireless links, while maintaining the advantages of TCP on the wired networks at the same time. This new outlook confers on TCP a good feature of adapting to wired and wireless environments. We evaluated our approach via simulation with NS3 and compared the results of H-TCP with standard TCP-Reno scheme and a recent improvement of TCP performed on the basis of the signal strength. This comparison is done in terms of transmission time, interferences and mobility of the nodes.

The numerical results reveal that H-TCP achieves a significant improvement in the TCP transmission performance over mobile multi-hop wireless. In this paper, we presented an essay to improve TCP performances in mobile wireless ad-hoc networks (MANET).Our enhancement is based on enabling TCP to distinguish between different causes of packet loss, as congestion, interferences or mobility of nodes. In this article we have represented the first results of the simulation which are obtained by using approximated factors and formula to compare H-TCP, TCP Reno and TCP with signal strength solution to prove that using H-TCP in ad-hoc networks gives the best result in comparison to other studied TCP versions.

R. BrittoPradeep at el we have simulated different networks with differing parameters to analyze the behavior of the most common protocols DSDV and AODV with different variants of TCP. By creating different networks in ns2 simulator, we could deeply analyze the behavior of the protocols with these TCP variants in the basis of the amount of packet drops in each case. The lesser the amount of drops the better the algorithm. This paper implicitly analyses which TCP variant has lesser drop rates with which routing protocol. To compare the performances of different TCP variants like TCP, TCP Reno, TCP NewReno, TCP Vegas and TCP Tahoe with the routing protocols DSDV and AODV, we have experimented in 20 different ways to find that TCP Tahoe has the least number of packet drops against the simulation time. Some of the other variants, though they start with a lesser number of packet drops, the TCP Tahoe variant has always the least amount of packet drops in all cases like when using AODV and DSDV, be it 50 nodes or 100 nodes. Hence, irrespective of the number of nodes being increased and the simulation time being increasing, the TCP Tahoe always has the least packet drops.

V.Jacobson at el. we shall discuss how the different mechanism affect the through put and efficiency of TCP and how they compare with TCP Vegas in terms of performance. Cause it is much more robust in the face of lost packets. It can detect and retransmit lost packet much sooner than timeouts in Tahoe. It also has fewer re-transmissions since it doesn't empty the whole pipe whenever it loses packets. It is better at congestion avoidance and its modified congestion avoidance and slow start algorithms measure incipient congestion and very accurately measure the available bandwidth available and therefore use network resources efficiently and don't contribute to congestion. 2) Reno: More than half of the coarse-grained timeouts of Reno are prevented by Vegas as it detects and re-transmits more than one lost packet before timeout occurs. It doesn't have to always wait for 3 duplicate packets so it can retransmit sooner. It doesn't reduce the congestion window too much prematurely. The advantages that it has in congestion avoidance and bandwidth utilization over Tahoe exist here as well. 3) New-Reno: It prevents many of the coarse grained timeouts of New-Reno as it doesn't need to wait for 3duplicate ACK's before it retransmits a lost packet. Its congestion avoidance mechanisms to detect 'incipient' congestion are very efficient and utilize network resources much more efficiently. Because of its modified congestion avoidance and slow start algorithm there are fewer retransmits. 4) SACK: TCP Vegas doesn't have a clear cut advantage over SACK TCP. The only fields where it appears to outperform SACK is: In its estimation of incipient congestion, and its efficient estimation of congestion by measuring change in throughput rather than packet loss. This would result in a better utilization of bandwidth and lesser congestion. Also it appears more stable than SACK. The reason for this being that SACK uses packet losses to denote congestion. So that the sender continually increase sending rate until there is congestion and then they back. This cycle continues and the system keeps on oscillating.TCP Vegas flattens out its sending rate at the optimal bandwidth utilization point thus inducing stability. Another advantage of TCP Vegas or rather the disadvantage of SACK is that it is not very easy to incorporate SACK in the current TCP. We need fields to acknowledge the selective segments and this requires changes at the receiver as well, whereas all the other mentioned algorithms only require changes at the sender side.

Mohit P. Tahiliani at el. The performance of high-speed TCP variants in multi-hop wireless networks in terms of network throughput. Another metric, expected throughput is used for comparison of throughput when nodes are mobile. Through simulations we have studied the behavior of high-speed TCP variants in multi-hop wireless networks by varying the routing protocols such as Destination Sequenced Distance Vector (DSDV), Ad hoc On demand Distance Vector (AODV) and Dynamic Source Routing (DSR) routing protocols. We have evaluated the performance of high-speed TCP variants in terms of throughput for static as well as mobile topologies. It is observed that the performance of TCP largely depends on routing protocols. The effect of application of SNOOP and ECN on the performance enhancement of TCP along with TCP variants is assessed, improving the performance of TCP over wireless network by implementing cross layer design protocol (Snoop). ECN is used to avoid congestion and Snoop aims at retransmitting the lost packets from base station, avoiding retransmission from the transmitter. The performance of different TCP variants such as TCP Tahoe, Vegas, Reno, New Reno, Sack are analyzed on Wi-Fi scenario. These results can be analysed from throughput and congestion window plots in the paper. The simulator used for implementation in Network Simulator-2 (NS2)

Manish DevendraChawhan at el. The effects of unidirectional and bidirectional networks on various TCP variants. The effect of application of SNOOP and ECN on the performance enhancement of TCP along with TCP variants is assessed, improving the performance of TCP over wireless network by implementing cross layer design protocol (Snoop). ECN is used to avoid congestion and Snoop aims at retransmitting the lost packets from base station, avoiding retransmission from the transmitter. The performance of different TCP variants such as TCP Tahoe, Vegas, Reno, New Reno, Sack are analyzed on Wi-Fi scenario. These results can be analysed from throughput and congestion window plots in the paper. The simulator used for implementation in Network Simulator-2 (NS2). The analysis of the result shows improvement in throughput of Vegas and E-Vegas with and without snoop with respect to other TCP Variants ie Reno, Newreno, Sack, and Tahoe. The analysis of the result for unidirectional network shows improvement in throughput of EVegas (49kbps) by 40% with respect to Vegas (35 kbps) (Fig 2.) and further the performance of TCP Vegas is improved by application of SNOOP in the Wi-Fi scenarios. The Throughput of all Variants increases and the throughput of E-Vegas reaches 51kbps (fig 3) which shows further 4% increase in the performance of TCP Vegas when snoop is applied.. ECN helps in congestion control and SNOOP will retransmit the packets that are lost from nodes in between, saving nearly half the retransmission time and avoiding the decreasing in transmission speed and an optimum transmission performance in a wireless network can be achieved. TCP Vegas is better than most of the TCP Variants and 'EVegas' is the best combination of variants for a unidirectional network, with as well as without SNOOP.

Poonam Omar at el compares TCP variants specifically TCP Tahoe, Reno and Lite based on different parameters such as number of nodes received with error, packet loss, byte received, and throughput and pause time. A table is then drawn which shows the comparison results. Congestion Control is a significant issue in Mobile Ad hoc Networks. The objectives listed in the problem statement have been carried out properly. In the presented work, all the simulation work was carried out using TCP variants (Reno, Lite, Tahoe) with DSR routing protocol .Network traffic is provided by using File Transfer Protocol (FTP) application. Everything is studied against various parameters such as, throughput, signal received with error, bytes received and packet loss while increasing the number of nodes. We sincerely hope that our work will contribute in providing further research directions in the area of routing.

David B. Johnson et al. presents Protocol for routing in ad hoc networks that uses dynamic source routing. The protocol adapts instantly to routing changes when host action is frequent, yet requires little or no overhead during periods in which hosts move less intermittently. Based on results from a packet-level simulation of mobile hosts operating in an ad hoc network, the protocol performs well over a diversity of environmental conditions such as host density and movement rates.

David B. Johnson et al. concluded that the overhead of the protocol is quite low, falling to just 1% of total data packets transmitted for moderate movement rates in a network. In all cases, the difference in length between the routes used and the optimal route lengths is slight, and in most cases, route lengths are on average within a factor of 1.02 of optimal [34].

III. PROBLEM OF OLD ARTICLE

2.1. Data-centric protocols: In many applications of sensor networks, it is not feasible to assign global identifiers to each node due to the sheer number of nodes deployed. Such lack of global identification along with random deployment of sensor nodes makes it hard to select a specific set of sensor nodes to be queried. Therefore, data is usually transmitted from every sensor node within the deployment region with significant redundancy. Since this is very inefficient in terms of energy consumption, routing protocols that will be able to select a set of sensor nodes and utilize data aggregation during the relaying of data have been considered. This consideration has led to data-centric routing, which is different from traditional address-based routing where routes are created between addressable nodes managed in the network layer of the communication stack. In data-centric routing, the sink sends queries to certain regions and waits for data from the sensors located in the selected regions. Since data is being requested through queries, attribute-based naming is necessary to specify the properties of data. SPIN [25] is the first data-centric protocol, which considers data negotiation between nodes in order to eliminate redundant data and save energy. Later, Directed Diffusion [18] has been developed and has become a breakthrough in data-centric routing. Then, many other protocols have been proposed either based on Directed Diffusion [26][27][28] or following a similar concept [16][24][29][30]. In this section, these protocols are described in details.

2.2 Flooding and Gossiping: Flooding and gossiping [31] are two classical mechanisms to relay data in sensor networks without the need for any routing algorithms and topology maintenance. In flooding, each sensor receiving a data packet broadcasts it to all of its neighbours and this process continues until the packet arrives at the destination or the maximum number of hops for the packet is reached. On the other hand, gossiping is a slightly enhanced version of flooding where the receiving node sends the packet to a randomly selected neighbour, which picks another random neighbour to forward the packet to and so on. Although flooding is very easy to implement, it has several drawbacks, see figures 2.1 redrawn from [25]. Such drawbacks include implosion caused by duplicated messages sent to same node, overlap when two nodes sensing the same region send similar packets to the same neighbor and resource blindness by consuming large amount of energy without consideration for the energy constraints [25]. Gossiping avoids the problem of implosion by just selecting a random node to send the packet rather than broadcasting. However, this cause delays in propagation of data through the nodes.

IV. POWER EFFICIENT GATHERING IN SENSOR

The life span of the network is extended in terms of rounds which is the process of gathering all the data from sensor nodes to the base station regardless of how much time it makes. Low-Energy Adaptive Clustering Hierarchy (LEACH), Power Efficient

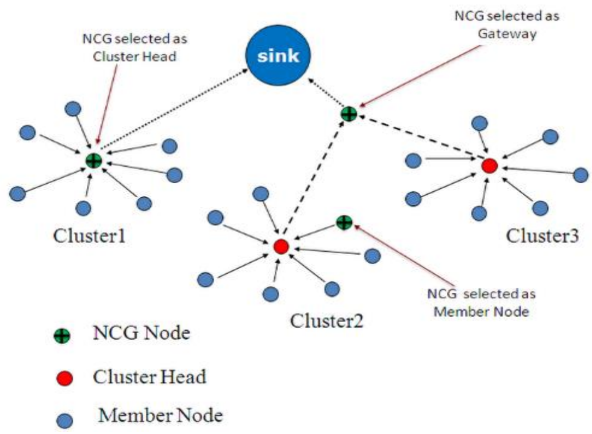

Fig 2.1 Flooding & Gossiping

Gathering in Sensor Information Systems (PEGASIS) [3], Hybrid Energy-Efficient Distributed clustering (HEED) [4] are algorithms designed for homogenous WSN under consideration so these protocols do not work efficiently under heterogeneous scenarios because these algorithms are unable to treat nodes differently in terms of their energy. Whereas, Stable Election Protocol (SEP) [5], Distributed Energy-Efficient Clustering (DEEC) [6], Developed DEEC (DDEEC) [7], Enhanced DEEC (EDEEC) [8] are algorithms designed for heterogeneous WSN. SEP is designed for two level heterogeneous networks, so it cannot work efficiently in three or multilevel heterogeneous network. SEP considered only normal and advanced nodes where normal nodes have low energy level and advanced nodes have high energy. DEEC, DDEEC, EDEEC and TDEEC are designed for multilevel heterogeneous networks and can also perform efficiently in two level heterogeneous scenarios

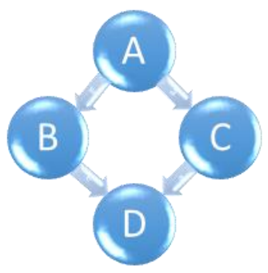

Fig 1: The implosion problem. Node A starts by flooding its data to all neighbors. D gets two same copies of data eventually, which is not necessary.

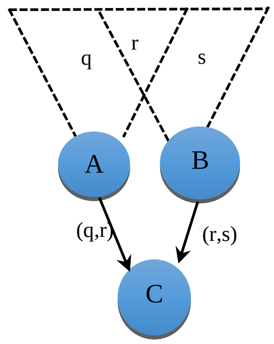

Fig 2: The overlap problem: Two sensors cover an overlapping geographic region and C gets same copy of data from these sensors.

Fig 3.1 LEACH Centralized

Proposed LEACH centralized (LEACH-C), a protocol that uses a centralized clustering algorithm and the same steady state protocol as LEACH. SEP (Stable Election Protocol) [5] is proposed in which every sensor node in a heterogeneous two-level hierarchical network independently elects itself as a cluster head based on its initial energy relative to that of other nodes. Li Qing et. al. proposed DEEC [6] (Distributed energy efficient Clustering) algorithm in which cluster head is selected on the basis of probability of ratio of residual energy and average energy of the network. Simulations show that its performance is better than other protocols. B. Elbhiri et al , proposed SBDEEC (Stochastic and Balanced Developed Distributed Energy-Efficient Clustering (SBDEEC) [10] SBDEEC introduces a balanced and dynamic method where the cluster head election probability is more efficient. Moreover, it uses a stochastic scheme detection to extend the network lifetime. Simulation results show that this protocol performs better than the Stable Election Protocol (SEP) and the Distributed Energy- Efficient Clustering DEEC) in terms of network lifetime.

V. CONCLUSION

Wireless sensor network is a combination of wireless communication and sensor nodes. The network should be energy efficient with stability and longer lifetime. In this paper, proposed E-DEEC adds heterogeneity in the network by introducing the super nodes having energy more than normal and advanced nodes and respective probabilities. Simulation results shows that E-DEEC has better performance as compared to SEP in terms of parameters used. It extends the lifetime and stability of the network.

VI. REFERENCES

[1]. Jamal N. Al-Karaki, Ahmed E. Kamal," Routing Techniques In Wireless Sensor Networks: A Survey", IEEE Wireless Communications, Volume: 11, Issue: 6, 26- 28, December 2004.

[2]. W.Heinzelman, A. Chandrakasan, and H. Balakrishnan, "Energy-efficient communication protocol for wireless sensor networks," in the Proceeding of the Hawaii International Conference System Sciences, Hawaii, January 2000.

[3]. S. Lindsey and C. S. Raghavendra, "PEGASIS: Power Efficient Gathering in Sensor Information Systems," in the Proceedings of the IEEE Aerospace Conference, Big Sky, Montana, March 2002.

[4]. O. Younis, S. Fahmy, "HEED: A hybrid, energy efficient, distributed clustering approach for adhoc sensor networks", IEEE Transactions on Mobile Computing vol 3, no 4, pp 660-669, 2004.

[5]. G. Smaragdakis, I. Matta, A. Bestavros, "SEP: A Stable Election Protocol for clustered heterogeneous wireless sensor networks", in: Second International Workshop on Sensor

[6]. L. Qing, Q. Zhu, M. Wang, "Design of a distributed energy-efficient clustering algorithm for heterogeneous wireless sensor networks". ELSEVIER, Computer Communications 29, 2006, pp 2230- 2237.

[7]. A. Manjeshwar and D. P. Agarwal, "TEEN: a routing protocol for enhanced efficiency in wireless sensor networks," In 1st International Workshop on Parallel and Distributed Computing Issues in Wireless Networks and Mobile Computing, April 2001.

[8]. A. Manjeshwar and D. P. Agarwal, "APTEEN: A hybrid protocol for efficient routing and comprehensive information retrieval in wireless sensor networks," Parallel and Distributed Processing Symposium., Proceedings International, IPDPS 2002, pp. 195-202.

[9]. W.R. Heinzelman, A.P. Chandrakasan, H. Balakrishnan, An application specific protocol architecture for wireless microsensor networks, IEEE Transactions on Wireless Communications 1 (4) (2002) 660–670.

Author is as on date working as a Technical Group 'A' officer with Directorate General of Civil Aviation, Ministry of Civil Aviation. He had work experience in Hindustan Aeronautics Ltd, AAI and Defense research and Development organization (DRDO)