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# ADEN:Adaptive Energy Efficient Network of Flying Robots Monitoring over Disaster Hit Area

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*Abstract*— **The post disaster mitigation is the immediate task to be carried out in disaster affected areas in order to reduce the extent of damage and for early rehabilitation and reconstruction. This paper proposes a design framework for an optimal control strategy to efficiently perform surveillance over a wide disaster hit area using a network of flying robots to determine the extent of damage promptly so that the rescue operation can be carried out efficiently. The main focus of the paper is to develop a low cost and an adaptive energy efficient strategy with less power dissipation and delay compared to traditional methods. The routing protocol proposed in the paper efficiently determines the best route by taking account of the residual energy, signal strength and various environmental factors. Simulation results show that the proposed routing scheme achieves much higher performance than the classical routing protocols.**

***Keywords-Flying robots; Mobile ad-hoc network; Energy efficient; collision avoidance; Routing protocol.***

## I. INTRODUCTION *(HEADING 1)*

In disasters such as large-scale earthquakes, flood, forest fire ,nuclear explosion etc it is important to undertake disaster-mitigation activities for reducing damage In particular, there is an increased need for information gathering systems to confirm the post-disaster status of the affected areas to perform rescue operations in an effective manner. Moreover, many cases have been reported in which problems have actually been caused by existing disaster prevention equipment that failed to work during a disaster. At present, rescue workers such as fire crews and rescue teams enter post-disaster spaces to determine the extent of damage due to the disaster. However in such uncertain situations rescue operations are limited because personal sufferings to the rescue operators are high.

This pays the way for the development of surveillance systems that can be controlled remotely. This paper presents a design of an optimal control strategy to efficiently perform surveillance over a wide disaster hit area where the extent of damage should be determined promptly.

The network consisting of flying robots equipped with sensors deployed over the disaster area will be utilized to detect the regions where there are more victims and the first responders can be effectively routed to these regions with higher priority. During disasters it is difficult for human rescue operators to reach the hard core area, also there is no guarantee on their safety. By using network of flying robots equipped with sensors, the worst affected area can be identified and it is possible to provide a map of that region to the responders and responsible authorities so that they can take necessary steps to route the responders to the area, with necessary safety measures. The network of flying robots can be considered as a mobile ad-hoc network (MANET), these networks have an important advantage, and they do not require any existing infrastructure or central administration. In this paper, a new routing protocol is presented which prolong the life time of the network by reducing the power dissipation by unwanted flooding of control messages and data packets. This protocol uses the metrics received signal strength and the available energy to identify an energy efficient path that minimizes packet collisions and increases the network lifetime.

The paper is structured as follows. Section II presents the existing systems that have addressed the issues regarding the disaster monitoring with unmanned aerial vehicles and flying robots. Section III introduces the proposed system architecture and discusses the various components used in the system and explains the new routing protocol and section IV discusses about the simulations carried out as an initial step to the realization of the proposed system. Finally, we conclude by section V

## II. LITERATURE SURVEY

The paper by K.M.Onosato et al [1] explains the use of aerial robots for quick information gathering of disaster area. Different types of aerial robot systems have been developed and they are systematically combined to offer continuous information gathering in a suffered area. Different types of aerial robot systems have been developed and they are systematically combined to offer continuous

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information gathering in a suffered area. Autonomous helicopters are used for collecting disaster situation data from the sky for urban search and rescue first operation planning. Then, a blimp-type robot system and a cable driven robot system are used to start to survey victims under collapsed houses in the destroyed areas. Continuously a captive balloon system with a monitoring camera presents bird's eye views of the disaster area continuously. These robots and other developed technologies are integrated to a total solution for a quick information gathering in USAR. This system uses three different aerial vehicles to assemble data during three different phases of the disastrous scenario. Whereas the multi-Robot network used in the proposed architecture are identical in nature and consistently monitors the disastrous area in real time.

Autonomous deployment and repair of sensor networks using aerial unmanned vehicle [2] described a sensor network deployment method using autonomous flying robots. Such networks are suitable for tasks such as large scale environmental monitoring or for command and control in emergency situations. This system has sensor networks that consist of static and dynamic nodes. The static sensor nodes are "Motes" and the mobile nodes are autonomous helicopter. Integrating static nodes with mobile robots enhances the capabilities of both types of devices and enables new applications. Using networking, the sensors can provide the Unmanned Aerial Vehicle (UAV) with information which is out of the range of the robot. Using mobility, the robot can deploy the network, localize the nodes in the network, maintain connectivity by introducing new nodes as needed, and act as "data mules" to relay information between disconnected wireless clouds. They use an autonomous helicopter to deploy a sensor network with a controlled topology, for example a star, grid, or random. The helicopter deploys the sensors one at a time at designated locations. Once on the ground, the sensors establish an ad-hoc network and compute their connectivity map in a localized and distributed way. Here in the proposed scheme focus is to develop an ad-hoc network for real time monitoring using flying robots itself and this can be used for deploying and establishing a sensor network at ground level at later point of time.

Swarms of flying robots inspired by insect behavior could be used to establish emergency rescue networks following natural disasters. After earthquakes and other disasters, when communication infrastructure is damaged or overloaded, the first thing rescue teams do is set up temporary communication networks to coordinate the search for survivors [3]. Now a team of scientists at the Swiss Federal Institute of Technology in Lausanne, has developed a quick way to establish a wireless network using 'swarming micro air vehicles' - flying robots.

The establishment of emergency communication using WiFi radio modules with optimal number of flying robots to monitor given area considering coverage and connectivity aspect has not been exploited yet. Since drastic power draining and recharging of battery of flying robot during monitoring is cited as a major problem in many of the previous research works, the paper focuses to minimize the power consumption in various stages of monitoring. since routing of gathered information is a major task an adaptive routing protocol with less power consumption by reducing unnecessary flooding of packets is introduced.

## III. System Architecture

Monitoring and sensing over an area immediately after disaster is restricted by the lack of communication infrastructure and also the delay encountered in the deployment of sensing units. Here sensing is performed by network of flying robots, the overall architecture of the proposed system is shown in figure 1. System consists of network of flying robots equipped with visual sensors for sensing, a radio module for communication and a control module. Control station located at a remote location controls the whole network; it reduces the need for large infrastructure to be deployed on site of disaster which is a great difficulty. The Wireless Flying Robots in the network communicates with each other in an organized manner using wireless communication techniques. The multiple flying robots are positioned in the lower atmosphere form an ad hoc network to perform efficient monitoring of the disaster hit area in real time

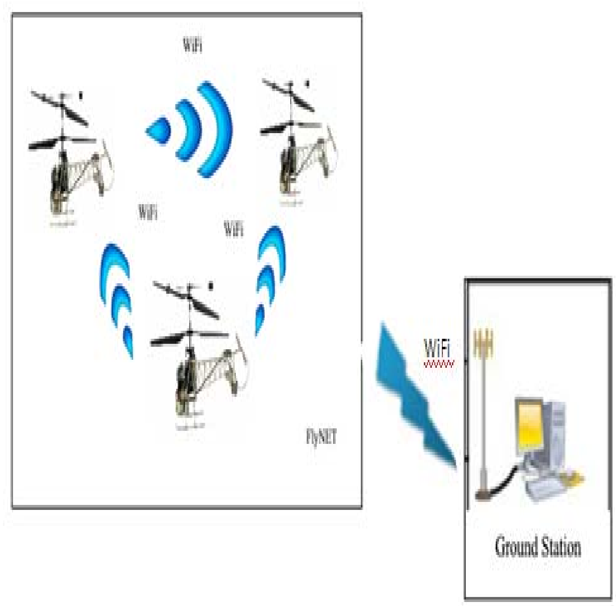


Fig1: Network Architecture

Two main sections of system architecture are FlyNET ie network of flying robots and the control station as shown in figure 2. The functioning modules of flying robot includes Autopilot which takes control of navigation part ,Routing module for the appropriate routing of information, Sensing part which contains various sensors for monitoring the disaster hit area and radio module for transmission and reception. Control station includes the following modules Laptop/Pc which performs controlling function, a radio module for trans- mission/reception and an interface to devices such as PDA or to rescue and rehabilitation centre.

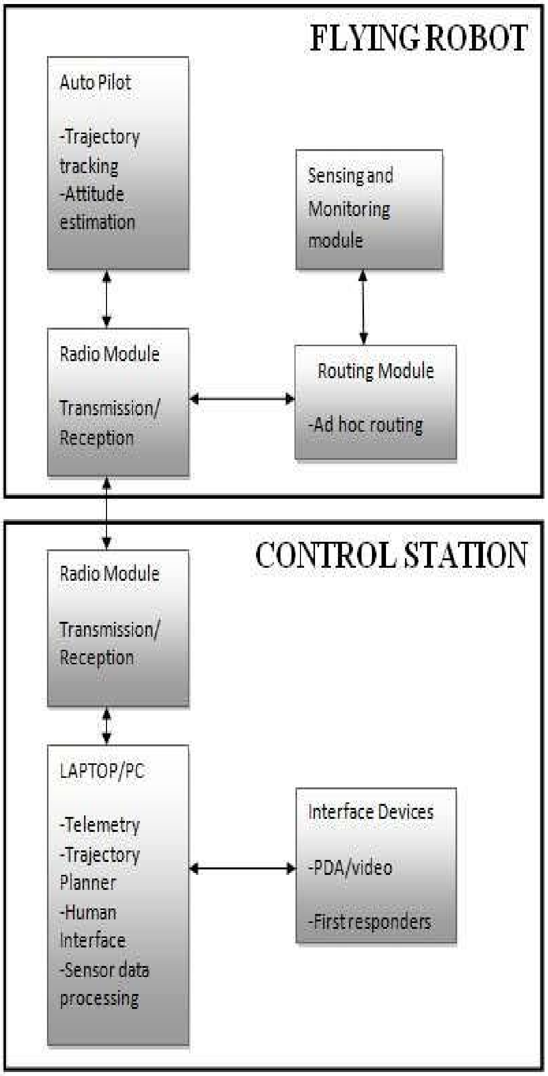


Fig2. System Components

### A. *Flying Robot*

As mentioned before flying robot basically consists of four modules. Autopilot receives commands from the control station from the ground and performs navigation, also the environmental propagation effects are taken into consideration. It receives the attitude and trajectory information's from the ground station. Sensing module is equipped with sensors or the real monitoring of disaster hit area.The sensing unit basically consists of visual sensors such as camera, pressure sensors, altitude sensor and temperature sensor. The optimal height to be maintained by the flying robots to get good quality image is determined by the control station. The sensing unit gathers information and gives the necessary information to the routing module.

### B. *Control Station*

Control station consists of wireless transmission reception module which is responsible for enabling wireless communication between flying robots and the ground Control station. The basic functional unit of control station is the Lap-top/PC which is responsible for processing of the sensor collected information and taking decisions based on the gathered information. It is the human interface part and is responsible for aiding the navigation support system. decisions such as assigning priority to the worst affected regions is taken here and the message s are send to the external inter- faces such as PDA or rescue rehabilitation centre for taking necessary action.

### C. *Routing Module*

We consider a network of mobile nodes ie a network of flying robots which forms a mobile ad-hoc network and these nodes are energy constrained since flying robots are run over battery power. Although researchers have focused on the implementation of energy aware routing [4,8,9,10,12,14] an efficient solution for this scenario has not been found out. I this protocol we assume that all nodes in the network are assigned with a unique ID and all nodes are participating in the network and forward the given data to the destination. Once a node has some sensed data to send it will check whether the control station (Destination) is in the range, then it will send data directly else a multi hop ad hoc routing is performed.

We assume that the control station have powerful resources to perform any tasks or communicate with the sensor nodes. To increase the network lifetime additional mechanisms are done in routing protocols to verify other parameters beyond the hop count that accept a more intelligent route establishment. The energy efficient routing algorithm proposed is used for making a decision on which neighbor a sensor node should forward the data message to. A node is selected to forward the data based on its residual energy level and signal strength. The nodes which are not selected in path establishment and those which do not have sufficient energy will move to the sleep state in order to conserve power. Algorithm assumes that initially HELLO packets are exchanged and each node knows its next hop neighbours and attribute value (T). We define following parameters:

- T=f(signal strength, residual energy, velocity)
- C=f(delay, number of hops)

Where C is the cost function of the path. And here after calculating the cost function of each path the one with minimum cost is selected such that delay is minimized. The algorithm is composed of three phases: Route discovery, Route maintenance and Route failure handling.

*1) Route Discovery:* In this phase new routes are created by means of propagation of Forward Agents and Backward Agents. Source adds timestamp and floods control packet FAGENT (forward agent), it consists of a unique sequence number, a field for hop length ,destination address and maintains a list F.list which has the list of all intermediate nodes in its way to the destination. FAGENT will be forwarded to the nodes which have the best T value.

Each node consists of the following fields: STATUS field to indicate whether a node is busy thereby avoiding collision when another packet is routed to this node, a field which stores attribute value, a field to store link quality parameter $ø_{ij}$ which indicates the usage of that link. When the same path is used for a long time, there is a probability for link failure so by using this parameter we are restricting the frequent use of a path there by increasing reliability. A field is assigned for DUPLICATE ERROR FLAG which is set to 1 when a duplicate packet reaches the node and a field to indicate the packet loss parameter *βij= lost packets/received packets*. When βij is set to 1 that node will be deleted from the routing table entries of all other nodes. When FAGENT reaches destination it extracts information and compute cost function for each path and select path with minimum cost function and sent back BAGENT in reverse path as that of FAGENT.

*2) Route Maintenance:* In this phase the back agents reaches the source and source is now ready to transmit data with header as the list of intermediate node ie F.list. Whenever a node receives a data packet it will increase its link parameter øij by an amount of Δp to indicate that that link øij has been used up for once and also reduces the attribute T of that node by an amount δ which is basically the amount of energy lost during single transmission of data packet. Whenever the value of link utility parameter goes beyond threshold value or whenever the attribute function of node falls below the parameter the corresponding node is switched to sleep and will never take part in routing process.

*3)Route failure Handling:* The third and last phase of algorithm handles routing failures, which are caused especially through node mobility and thus very common in mobile ad-hoc networks. Algorithm recognizes a route failure through a missing acknowledgement. If a node gets a ROUTE ERROR message for a certain link, it first deactivates this link by setting the βij value to 1. Then the node searches for an alternative link in its routing table. If there exists a second link it sends the packet via this path. Otherwise the node informs its neighbors, hoping that they can relay the packet. Either the packet can be transported to the destination node or the backtracking continues to the source node. If the packet does not reach the destination, the source has to initiate a new route discovery phase. Reliability of packet delivery is ensured such. Data is cached in the sender until an ACK is received from the receiver. If no ACK is received within a timeout period, an error report is generated and the data will be sent back to the original source of this data in order to retransmit the data.

## IV. Experimaentation And Results

The experimental set up analyzed the performance of network with limited number of nodes as we assume that the flying robots have limited mobility and monitor over a fixed area of the proposed protocol and its comparison with existing protocol 'Dynamic Source routing' is carried out and results obtained are cited in this section. The following factors are considered for comparison

### *A. Performance metrics*

*Packet loss:* Packet loss parameter is defined by βij= lost packets/received packets at each node. Higher packet loss indicates the un reliability of the link and it is not desirable. From results it is found that the packet loss ratio for the new protocol is less as more emphasis is given for finding paths that are more reliable.

*Delivery Ratio:* The delivery ratio gives an indication about the amount of packets that are (successfully delivered=1-packetloss rate). If the ratio is considerably high it indicates some fault in the network. This is not desirable and alternate path has to be determined.

*Delay:* It is defined as the average time between the sending and reception of data packet. Delay is reduced as the probability of selecting path with minimum number of hope is high. This metric defines the freshness of data packets.

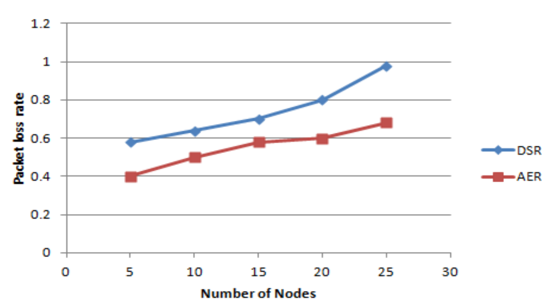


*Fig3:* Packet loss Vs Number of nodes

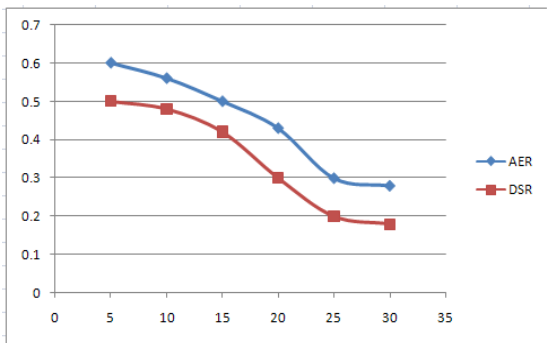


*Fig5:* Delivery Ratio Vs Number of nodes

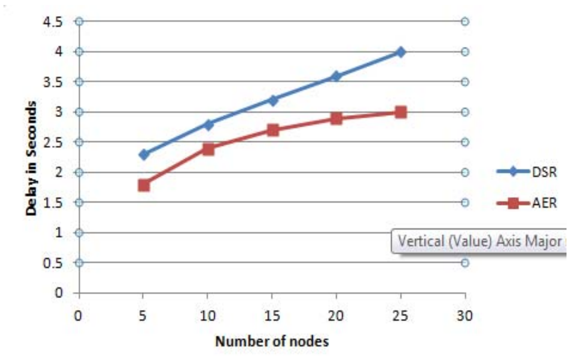


Fig5: Delay Vs Number of Nodes

## V. Conclusion

This paper mainly focuses on routing in the flying robot network. The system consists of functional units for collaborative sensing, monitoring, adaptive routing for the gathered information's and wireless transmission of the intended data. Since Battery power is major concern in flying robots and also the propagation effects affect the transmission adversely, a routing strategy was developed which considerably reduces the number of transmissions in a wireless ad hoc network. Also optimization of the network and efficiency of the proposed protocol need to be analyzed by implementing the system in real world. By analyzing the connectivity and coverage aspects and incorporating them in the routing strategy the resources can be efficiently utilized. Apart from energy efficiency we need to consider the cost and the performance metric of the network when considering the real time case.


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