Low Power VTOL UAV Deployments for Urban Area Monitoring

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***Abstract*—Real time monitoring of urban areas and densely populated city centers for criminal activity is a major challenge faced by the police force globally. The interlocking street networks provides a means of escape for criminals and makes it costly and time consuming for law enforcement agencies to track and capture these criminals. Cameras installed in streets and shops provide some form of identification which can be used for tracking but it has a limitation when the criminals are in motion. Helicopters are currently being used by security agencies to provide real time aerial monitoring of urban areas but the cost implications and deployment time of this service are key challenges with this approach. This paper proposes the use of the low power Vertical Takeoff and Landing type Unmanned Aerial Vehicles (VTOL-UAV) as a tool to be deployed for the monitoring of the city centers in the event of emergencies such as disasters and criminal activities. The cities are divided into wide area cells with a VTOL UAV allocated to the cells. Whenever an alert is raised, the closest VTOL UAV is deployed immediately to provide aerial surveillance. The video feeds from the UAV are monitored from the local police department and this information is used to provide guidance to the security agents in pursuit.**

***Index Terms*—Aerial surveillance, information, cell, low power**

I. INTRODUCTION

THE rapid urbanization and densely populated city centers create bottlenecks for the monitoring of criminal activity and the real time tracking of persons and assets.

The interlocking street networks provides a means of escape for criminals and makes it costly and time consuming for law enforcement agencies to track and capture these criminals. The approach currently being deployed to monitor urban areas during disasters and pursuit of criminals involves the use of helicopters by security agencies to provide real time aerial monitoring of urban areas. The cost implication, availability and deployment time of this service are key challenges that limit the deployment frequency of helicopters.

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Low power vertical takeoff and landing type Unmanned Aerial Vehicles (VTOL-UAV) are a type of UAVs that can be deployed without the need for runways. They are mostly battery powered and can be deployed for the monitoring of the city centers in the event of emergencies such as disasters and criminal activities. The cities are divided into wide area cells with a VTOL UAV allocated to the cells. Whenever an alert is raised, the closest VTOL UAV is deployed immediately to provide aerial surveillance. The video feeds from the UAV are monitored from the local police department and this information is used to provide guidance to the security agents in pursuit or for the aid/ volunteers during disasters.

II. MONITORING APPROACH

A. *Wide Area Monitoring of Urban centers*

City centers are often characterized by high population densities with a constant flow of people moving from the suburbs and rural areas to the urban areas. This often leads to an over population of the urban areas with a high population of jobless inhabitants. The increase population densities and the lack of adequate jobs and housing in the city center leads to an increase in the crime rates [1] [2]. For the security agencies to maintain a state of safety for the dwellers, they have to be able to respond quickly and adequately to all distress calls and have a very high rate of success in tackling crime.

The current approach at ensuring this involves the use of an array of security agencies ranging from the police to the soldiers. The deployment of the agencies is dependent on the nature of the security threat. For criminal activities which constitute the bulk of the security challenges, the city relies on the police men and women. This leads to the requirement of a large number of police men/women, Police cars and helicopters etc.

Wide area monitoring involves the subdivision of the city into cells. The dimensions of the cells are determined by the range of the UAVs covering the cells and each cell is selected to cover a base station tower. To ensure rapid response to the alerts and distress calls, there is a need for a system that can enable the police men respond as quickly as possible and also track the location and events in real time.

B. *Unmanned Aerial Vehicles*

UAVs are Unmanned Aerial Vehicles or aircrafts deployed with or without the control of human operators

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and they are used to provide video information over a location. The component systems that make up the UAV include the air vehicle, the ground control station, payloads, data link and support equipment [3]. The UAVs have been utilized more by the military for reconnaissance missions and are currently finding more and more applications in civilian and urban applications.

The UAVs are classified according to their:
1. Weight
2. Endurance and Range
3. Maximum Altitude
4. Wing Loading
5. Engine Type
6. Power/Thrust Loading

III. COMMON APPLICATION AREAS

The most popular applications of UAVs include:

A. *Aerial Reconnaissance*

UAVs are often used to obtain aerial video of remote locations, especially where there would be unacceptable risk to the pilot of a manned aircraft. UAVs can be equipped with high resolution still, video, and even infrared cameras. The information obtained by the UAV can be streamed back to the control centre in real time [4].

B. *Scientific Research*

Scientific research often necessitates the obtaining of data from remote and sometime hazardous locations where a manned aircraft would pose a risk to the pilot. A UAV can be used to obtain data from such locations with no risk to a human pilot.

C. *Logistics and Transportation*

Helicopter type UAVs can be used to carry and deliver a variety of payloads. The suspension of the payloads at the bottom of the helicopter makes it immune to any aerodynamic drag.

IV. VERTICAL TAKE-OFF AND LANDING

These are portable UAVs that do not require a runway and can be easily transported, deployed or stored. Another key feature is the fact that they are powered by electric motors and are designed to take off vertically. Vertical Take-Off and Landing UAVs are able to generate downward thrust and take off within a very limited space. They are utilized in locations where runway facilities are inaccessible such as operations in forest or bush areas [5].

A. *VTOL Configurations*

The most popular architecture for urban surveillance is the quad-rotor type. With this type, flight control is achieved by changing the speed of each rotor. The rotor blades are all fixed in pitch and thrust is achieved by changing the speed of rotation. Each rotor is individually driven by an electric motor mounted at the rotor head [6]. Thus, for example, for the aircraft to move forward, the rotational speed of the two rear motors would be increased to pitch the aircraft nose-down and direct the resulting thrust vector forwards. At the same time, the total thrust must be increased to prevent loss of height.

B. *Functional Structure of a UAV*

The UAV consists of the navigation interface, the payloads and the communication interface. The UAVs can be pre-programmed to fly over a pre-determined route or can be controlled by the operator at the ground control center in real time. The payloads can comprise of different types of cameras with zoom capability for capturing real-time video during the day and transmitting same to the ground control station.

C. *VTOL-UAV Advantages*

The key advantages of the VTOL UAV include [7].
1. Ease of deployment
2. Speed of deployment
3. Low cost deployment
4. Long flight endurance
5. Stealth ability
6. Long Battery power
7. Ability to carry specialized cameras and payloads
8. Steerable directional antenna to increase transmit range

V. UAV APPLICATION FOR WIDE AREA MONITORING

A. *Response to distress calls*

Most homes are fitted with telephones systems and the individuals also have mobile phone. Existing distress call protocol include the dialing of 911 and the response agencies are able to locate the source of the calls and get the details of the distress before dispatching the nearest police patrol team to that area. A distress call from a landline is easy to localize due to the hardwiring of the phone to the homes.

However for mobile phones, the callers need to specify their location before a patrol team can be dispatched. The Use of mobile phones makes it difficult to automatically localize the distress caller especially if the caller is either unable to give his address or doesn't know the address. With the mobile communication technology, the geographical locations are broken down into cells as shown in fig 1 and the cells are further subdivided into sectors with antennas providing coverage for each sector [8].

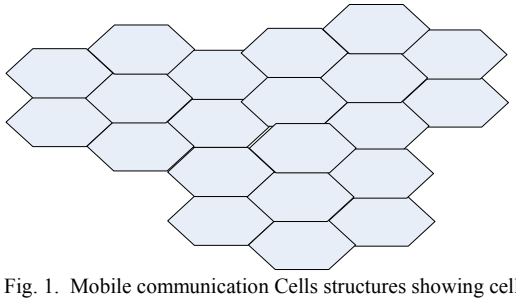

Fig. 1. Mobile communication Cells structures showing cells

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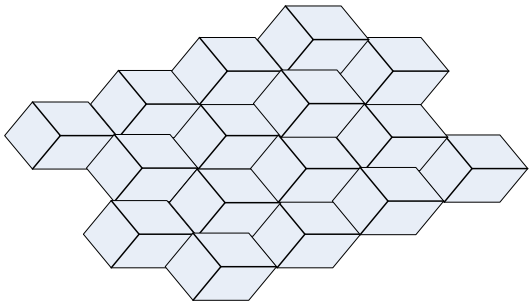

Fig. 2. Mobile communication Cells structures showing Sectors arrangements

The system is able to locate the phone by identifying the sector antenna through which the phone was able to communicate. The disadvantage with this approach is the fact that the antenna provides coverage to a wide area and thus it is difficult to pinpoint the location of the mobile for during emergencies.

The use of triangulation using the reading from the three nearest base stations enables the coarse localization of the mobile. The deployment of the UAV will enable the visual feedback of the coarse location of the distress call and the actual location can be identified by the analysis of the video in the office location.

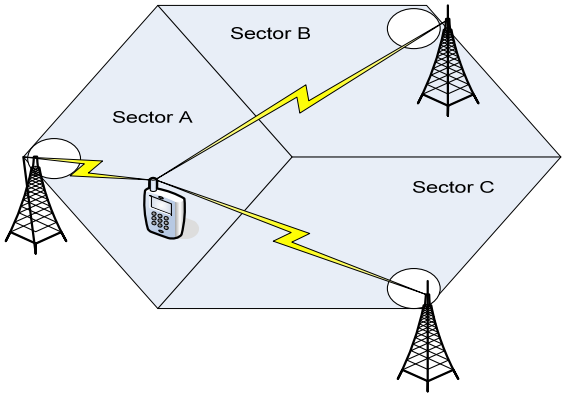

Fig. 3. Mobile phone localization using Triangulation

From fig 3, the mobile phone is located within a particular cell which has a radius of 1-30km (macrocell). The use of sector antennas further reduces this cell sizes to between 200 – 2000m for microcells and 4 – 200m for picocells [9]. With the triangulation algorithm, the location of the mobile phone which is in sector A can be further narrowed down by the use of the signal strength reading from the two neighboring sector antennas received by the phone.

These reading combined with received signal strength of the antenna in sector A can be used to narrow down the location of the phone while the UAV provides the video coverage of this location to the monitoring stations in the office where specialized software can be used to pinpoint the actual location.

B. *City center monitoring and event tracking*

The deployment of UAVs for city monitoring involves the deployment of the UAVs carrying specialized night vision cameras for the purpose of patrolling security critical areas. This will minimize the need for patrol officers moving round the neighborhoods. The camera images can be processed in real time for motion detection. Whenever motion is detected in a particular street, the image is analyzed and sent to the patrol vehicles.

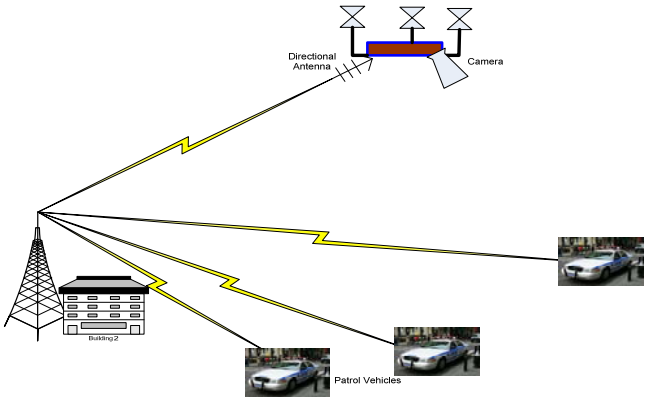

Fig. 4. Architecture for the deployment of VTOL UAV for city monitoring

C. *Benefits of the system*

The benefits of this system include

1. Improved response time of the security agencies to distress calls
2. More effective surveillance and street monitoring
3. Low cost deployment of monitoring services
4. Improved accuracy at identifying distress calls from Mobile phones
5. Increased success rate at apprehending criminals during pursuit

VI. Conclusion

With the ever growing population in urban area, the deployment of UAVs will enhance the ability of security agencies for the monitoring and security of lives and properties. It is a cost effective approach for managing the increase in criminal activities and emergencies with improved response times as compared to regular land patrols by security operatives.

Furthermore, the ability of UAVs to maintain a position for a prolonged period of time offers operational advantage over the helicopters. It also provides a quick and reliable information gathering system for real-time streaming to the control center for proper coordination and deployment of adequate resources to address the security challenges effectively.

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