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UAVs for Smart Cities: Opportunities and Challenges

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Abstract— **This paper discusses the applications of unmanned aerial vehicles (UAVs) in smart cities, their opportunities and their challenges. UAVs have a wide range of applications in many fields like environmental hazards monitoring, traffic management and pollution monitoring, all of which contributes greatly to the development of any smart city. These opportunities among several others are discussed in this paper. Several challenges and issues such as safety, privacy and ethical uses are of great concern and are also provided in this paper.**

Keywords— UAVs; smart cities; opportunities; challenges; environmental hazards monitoring.

I. Introduction

Unmanned Aerial Vehicles (UAVs), as shown in Figure 1, like any inventions and innovations were only used for military purposes. However, currently they became widely used in civil applications, which will be discussed in this paper. Those applications are in many areas such as agriculture, environmental protection, public safety and traffic flow control. In addition, one of the emerging areas of UAVs is their involvement in smart cities.

Figure 1. A typical UAV [12]

The main goal and aim of any smart city design is to provide efficient infrastructure and services at reduced costs. The European Platform for Intelligent Cities and the European Network of Living Labs defined smart cities as "The use of discrete new technology applications such as RFID and Internet of things through more holistic conception of intelligent, integrated working that is closely linked to the concept of living and user generated services [1]. Generally, the smart city is the city that seeks to achieve the objectives of a future city by utilizing information and communication technology (ICT) solutions and trends.

The interest in smart cities is increasing day by day especially after the global financial recession. The world population is increasing and it is foreseeable to be doubled by 2050. Consequently, these expectations create new challenges and opportunities for cities and communities. Therefore, there is increased interest to focus on utilizing ICT services and smart solutions in long-term smart city development [2].

Design of such a smart city requires huge and full integration of ICT and its trends. UAVs contribute to these goals. That is why UAVs are involved in a wide range of applications and functions in smart cities. These applications include monitoring traffic flow to measuring and detecting floods and natural disasters by using wireless sensors. This development is done based on technical reports published by technical institutions. Furthermore, many opportunities for UAVs and their applications in smart cities will continue to increase at a fast pace [3].

A report prepared by McKinsey and Company shows that worldwide expenditure on construction and infrastructure is about 2 trillion US Dollars per annum and ICT expenditure is about 1.5 to 2% of that number [4]. However, during the coming decade, the advances are expected to continue in areas of cloud computing, wireless sensors, networked unmanned systems, big data, open data, and Internet of things. In addition, billions of devices are going to be connected together. Consequently, there will be a substantial opportunity for using UAVs in Smart Cities.

Transforming any city into a smart city is the current trend of the world in terms of development. It will leverage new technologies like the Internet of Things, Cloud computing to build a connected and sustainable Smart City. This gives

ample opprtunity to introduce UAVs to help achieve the goal. UAVs can provide several services and opprtunities that can benfit smart cities.

This paper aims at providing insight on the use of UAVs in smart cities. Section II provides an overview of UAVs and smart cities. Section III provides some background information for Sections IV and V. Section IV discusses the opportunities of UAVs in smart cities, while Section V addresses the challenges and other concerns of UAVs in such environment. Section VI concludes the paper by mentioning some open issues.

II. Background

To integrate two technologies together that will improve a country's economy, one must understand the essentials of those technologies, the uses, the benefits and the advantages.

A. Unmanned Aerial Vehicles

UAVs have a wide range of applications and models. They are categorized into three categories, which are safety control, scientific research, and commercial applications.

However, to achieve a well-designed UAV application there must be an accurate information support, which is necessary for a successful system. It is well known that UAV applications have become involved in many industries ranging from agriculture to oil and gas production and transport.

The architecture of a typical UAV consists of main components comprising of the control system, the monitoring system, the data processing system, and the landing system. The internal system provides a wide range of functions ranging from navigation to providing data transfer to ground. The UAV market is still growing, and UAVs are involved in new activities and solving new problems every day. Many organizations are interested in developing UAVs in order to reduce the cost of the related services [5].

To date, some of the inhibiting factors for using UAVs in many civilian applications include the cost of acquiring these devices, building the required applications, and the operating systems. UAVs are easy to deploy, they have flexibilities in performing difficult tasks, supporting high resolution imagery and covering remote areas. On the other hand, a device with such abilities must have some ethical and legal impacts. Some countries have privacy and data protection acts and laws. However, most of the UAV applications were mainly deployed in the military and security fields. Generally, the issues that were raised were safety, privacy and ethics that will be addressed in the challenges section.

UAVs at the beginning were known for their military use, which gave some people a limited view of this technology. When the UAVs were allowed to serve in civil applications, the image of UAVs changed and it provided the media with a good representation and good impression about UAVs. In addition, UAVs were involved in some humanitarian activities, such as monitoring areas affected by hurricanes. For example, in Nepal, UAVs were involved in wildlife protection. The Non-Governmental Organization (NGO) that was involved in the project trained the guards on how to use UAVs in protecting the wildlife, which helped stop some crisis. NGOs in Japan use UAVs to monitor illegal Japanese whaling in the southern hemisphere. That is what gave the research and technical communities a good impression about UAVs and encouraged their use [9].

Figure 2. A Surveillance-based Dragon Fly UAV [13].

B. Smart Cities

Understanding the term 'Smart City' is not completely carved in stone as there are only limited number of studies that investigated this topic. However, with increasing advances in technology, information systems and communications, one can identify several important core components that are required to fully understand and define the concept of a smart city.

There are eight core factors that influence smart city initiatives [10]. These are:

- *Management and organization*: the alignment of management and organizational goals is a necessity for smart city to work effectively and efficiently.
- *Technology:* a smart city relies on a collection of smart computing technologies applied to critical infrastructure components and services. Smart computing refers to a new generation of integrated hardware, software and network technologies that provide IT systems with real time awareness of the real

world and advanced analytics to help people make more intelligent decisions.

- *Governance:* it involves the implementation of processes with constituents who exchange information according to rules and standards in order to achieve goals and objectives. Several factors like collaboration, communication, leadership, and data-exchange are required for effective smart city governance.
- *Policy-context:* the policy context is critical to the understanding of the use of information systems in appropriate ways. It mainly characterizes institutional and non-technical urban issues and creates conditions that enable urban development.
- *People and communities*: smart city initiatives allow members of the city to participate in the governance and management of the city and become active participants. If they are key players they may have the opportunity to engage with the initiative to the extent that they can influence its success or failure.
- *Economy:* it is one of the major drivers of smart city initiatives and a city with a high degree of economic competitiveness is thought to have one of the properties of a smart city. The outcomes are mostly business creation, job creation, workforce development, and improvement in productivity.
- *ICT infrastructure:* the implementation of an ICT infrastructure is fundamental to a smart city's development and depends on some factors related to its availability and performance.
- *Natural environment:* one of the core goals of a smart city is to increase sustainability and to enhance natural resource management. In addition, the protection of natural resources and related infrastructure is extremely important.

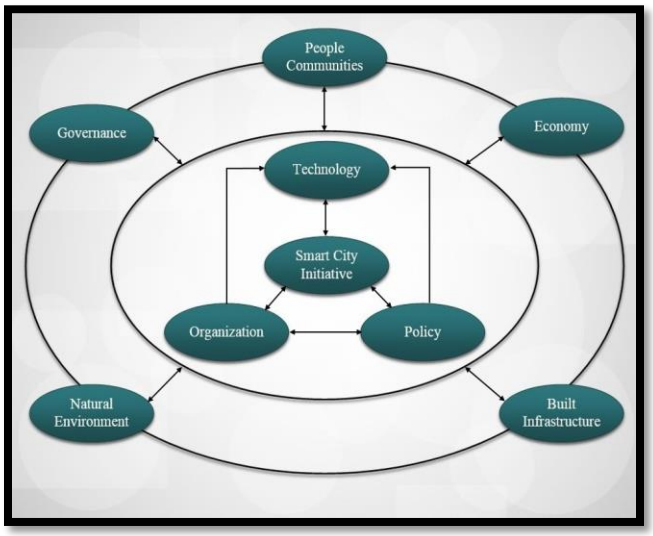

Figure 3. Smart city success factors [10].

Why should a city be transformed into a smart city? Conventional cities will face many challenges during the coming decades, which will affect the development and sustainability of these cities. The challenges include:

- The rapidly increasing populations
- Polarized economic growth, which requires more areas that are occupied by people.
- The environmental emissions and the sustainability requirements.
- The global economy instability.

Therefore many countries began transforming some of their cities into smart cities by utilizing the advancements in ICT to increase efficiency, reduce cost and improve the quality of life. But still there are some factors that affect the smart city development such as:

- The scaling of new technologies is unverified.
- Technology challenges the existing status quo in managing and running the city.
- Technology awareness among the city sectors and actors.

To develop smart city solutions, the complexity of how smart cities are operated, financed, regulated and planned need to be highly considered. Therefore, the paper in [18] claimed that any smart city structure consists of four layers as shown in Figure 4:

- City objectives: social, technological environmental and economic aims and goals.
- City indicators.
- City Components.
- City Contents: solutions and services.

Figure 4. Smart City Layers [18].

The main goal of any smart city design is to create a sustainable place where people can live, work and play. Therefore, the paper in [19] divides the smart city development into elements as shown in Figure 5. These are smart city infrastructure, smart database resources, smart building management systems and smart interface. These elements integrated together make up the smart city.

Figure 5. Smart City Development Elements.

III. Discussion

Since UAVs were used for military applications, allowing them for civil use generated certain issues. The most important one being the regulations needed to use them conveniently. This topic has been the topic of a great debate recently. Finally, the Federal Aviation Administration (FAA) [11] authorized the civil use of UAVs. They can be employed for public use provided that the UAVs are flown at a certain height level. Figure 6 categorizes the airspace in accordance to the FAA classification.

The FAA pays a lot attention to Class A — all U.S. airspace from 18,000 to 60,000 feet — where commercial planes fly. This is followed by the airspaces around airports, called Class B (big airports), C and D (smaller cities). Class G (700-1,200 feet), which is unregulated airspace is allocated for the use of UAVs for civilian use.

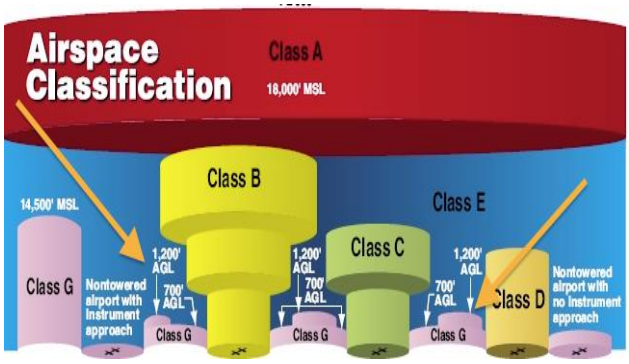

Figure 6. FAA Airspace Classification [6].

IV. Opportunities

Several opportunities for UAV use to support a smart city exist and these will be discussed in this section. These opportunities will be very beneficial to any smart cities that would utilize UAVs for their economic growth and development.

1. Geo-spatial and Surveying activities:

One of the new trends in UAV civil applications in smart cities is using UAVs in geospatial surveying. The main design of a smart city requires the optimization of data flows provided by wireless sensor networks as sensors are the main component of any autonomous system such as those involving UAVs. The system also requires real time processes integrated with the available information repository, since the handheld devices and wireless sensors are known for their low power consumption and high performance. This can provide a tool for the smart city technological base. This combination of technologies creates a wide range of applications and opportunities such as fire management in open areas where the use of UAVs and micro-UAVs is very beneficial. The potentials vary from a wide range of available solutions and innovations that are evolving quickly. Yet, the obstacles and difficulties to UAV system deployments are linked to political and cultural issues to a greater extent than the cost and benefit issues. Due to the reliability of most UAV designs, integration of such technologies make it possible to install wireless sensors on-board to make the UAVs usable in geospatial, land surveying and Geographic Information System (GIS) applications in smart cities in addition to being helpful for environmental analysis. These opportunities may lead to cost reduction and cutting down on the number of manpower hours involved in such activities.

2. Civil Security Control:

The integration of UAV solutions with M2M, RFID, LTE, and live video streaming increased the role of UAVs in public safety areas. In addition, the trends toward intelligence and data mining gives the UAVs an

opportunities to be involved in civil security activities, like providing the security services for smart cities. This new trend will move the cities management personnel from being reactive to proactive and leveraging data. Furthermore, involvement of UAVs in surveillance activities will reduce costs and increase the efficiency of the operations.

3. Traffic and Crowd Management:

Efficiency of security and safety systems in a city have become a serious concern not only for a smart cities but also for any type of cities or communities. Involvement of UAVs in smart policing activities have lately been supported by the US congress and top level federal agencies such as the Bureau of Justice Assistance, and the US Department of Justice. In addition, integration of mobile applications, secure and reliable wireless networks, forensic mapping software, and UAVs can help smart cities become a safe place for living. Figure 7 shows a law enforcement UAV.

4. Natural Disaster Control and Monitoring:

Using UAVs in disaster situations like fires, floods, and earthquakes will help the authorities control such emergency situations efficiently and effectively. UAVs will analyze the situation properly and also help in acting properly in certain disastrous situations because the UAVs can reach in areas that humans cannot reach. Figure 8 shows a picture of a UAV that is being used in firefighting.

5. Agriculture and Environmental Management:

The UAVs can be used to fertilize the crops by dropping fertilizer/water from above using UAVs. Also it can be used to monitor the growth of crops. Also they can monitor the environment by using the wireless sensors that can measure environmental substances such as CO_2 emission and other harmful substances, which will allow them to monitor oil and gas facilities.

Figure 7. A Law enforcement UAV [15].

6. Urban Security Increasing the city's attractiveness:

One of the UAV's opportunities in smart cities is security management (Urban Security). Usage of UAV's in such area will allow the city to deploy a quick operations room, updated with efficient data flow and will allow the city to manage big public events with huge numbers of attendee's smoothly and also provide a full technical coverage.

Figure 8. A firefighting UAV named Knight Hawk [14].

7. Big Data Processing:

Big data processing systems for smart infrastructure applications will require different technologies like:

- Integration with GIS
- Time series data processing
- Utilization of equipment structure
- Combination with modelling and simulation

Through UAVs the integration between the technologies can be achieved or at least made easier as the sharing of information among them can be fast and accurate.

8. Coordination between heterogeneous systems:

UAVs can act as a third party technology to coordinate information from various systems. Since they are controlled at the ground station once they receive information the ground system can send command to UAV to direct the information to another system or UAVs.

V. Challenges

The challenges can be classified into business and technical ones, which will be discussed in this section

1. Business challenges:

a. **Ethics and Privacy:** many would not approve the use of UAVs for monitoring and surveillance of the general population as they may think of it as an invasion to their privacy as mentioned in [8]. This created a huge debate in the United Kingdom because people are protected by the Data Protection Act. In case of ethical issues, the main challenge would be the wrong utilization of

UAVs. Since they are open for general use, they could be used wrongly such as for spying on others.

b. **Cost:** Developing UAVs can be expensive because of their technical issues, deployment issues, training and integration of systems. Designing a UAV for a specific service is also expensive as it needs to function properly. (P. Malone et al., 2013) [7] describes a cost estimation requirements for developing UAVs which can be used for developing UAVs.

c. **Licensing and legislations**: To use UAVs in a country it should be at first registered in that location. Flying UAVs might affect the airplanes and the navigation of their routes. So, a country must develop related regulation and legislation for UAV deployment and use.

d. **Business adoption**: It is a challenge to companies to introduce UAVs to run certain aspects of their business because this requires costly additional resources. However, if UAVs are used, they can be very helpful for the business to gain strategic advantages. For example after Amazon introduced their own drone, as shown in Figure 9, named Prime Air, it created a huge competition with UPS, which is another delivery giant. Prime Air UAVs can deliver products purchased from Amazon.com to the customers within 30 minutes.

Figure 9. Amazon UAV Prime Air [16].

2. Technical challenges:

a. Adaptable middleware is required to ensure smooth operation of UAVs. Proper integration of the middleware services with the UAV is also an additional challenge.

b. Development of fail-safe systems, to guarantee high safety confidence levels in the event of aircraft failure, or loss of all communications between the UAV and the control center.

c. Development of very efficient, low vibration, engines and a gyro-stabilized platform technology, for high resolution imaging and accurate measurements of gravitational field strength.

d. Demonstration of precision flying, in terms of altitude and flight path, over extended periods of time, in all weather conditions during both day and night periods.

e. Wireless sensors can be used for smooth operations of UAVs. For example, surveillance and live feed from wireless sensors can be used to control traffic systems.

f. Development of sense and avoid mechanisms enables a UAV to become aware of its environment enabling it to take evasive action if necessary.

g. Development of automated image data compression algorithms, stitching of aerial imagery. Data fusion software can intelligently fuse many pieces of information from a large number of sensors. Subsequently, automated computer-based interpretation of data can take place.

h. Development of a Network Centric infrastructure, to enable any member of a team to control the UAV and retrieve imagery and sensor information, in real time.

Several cities in the world like Malta (Republic of Malta) and Kochi (India) have already adopted such advanced technology. The smart city approach does not only aim to maintain the quality of life of the residents and visitors, but also to improve living by leveraging the IT infrastructure and the novel communication technologies. A smart city is a model of efficiency, innovation, and ubiquitous access to a wide range of services. A city's smartness can be assessed along several axes including smart living, smart economy, smart tourism, smart environment, smart mobility, and smart governance. For example, United Arab Emirates is now focusing on developing *Smart Dubai* an initiative that will completely change and revolutionize the quality of life of its people. After winning the Expo 2020 their need and drive for being smart just strengthened. This provides a great opportunity to develop UAV applications that can help achieve these goals.

Several of these opportunities involve areas such as intelligent traffic management, security and privacy when using smart systems, environment and ecosystem monitoring, development of smart malls, and much more. All of these opportunities can be achieved using UAVs in smart cities

VI. Conclusion

For the coming decade many technologies will change the world and transform the economy. Those technologies include the Internet of Things, autonomous systems like UAVs, and cloud computing among others. Integrating UAVs with smart cities will create a sustainable business environment and a peaceful place of living. Already plans are underway to develop smart government, and with the smart city initiative rapidly taking hold and acceptance, people can expect great improvements in the citizens' way of life. Several open issues need to be considered with the development and use of UAV systems for smart cities. Examples include the proper use of wireless sensors, data communications, application management, resource training and allocation, and power management. Finally, we can safely state that UAV systems and smart cities can significantly impact and benefit any country when used effectively and efficiently.

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