Quad-Copter Range Expansion using Ad Hoc network

[1]Majida S. Ibrahim, [2]Dr. Aymen Dawood Salman, [3]Dr. Salih Mahdi Al-Qaraawi
[1,2,3]Department of computer engineering, University of Technology

***Abstract*— Quad-Copter is a certain type of Unmanned Arial Vehicles UAVs, due to its stability, maneuverability and easy to design and implementation had been used in a variety of applications that serve humanity in many fields such as, military, industrial, commercial, surveillance, etc.**

In this paper, Quad-Copter had been used along with Ad-hoc network mechanism to design a prototype of a system that can be developed to be used early mentioned applications, with range more than that can be achieved via single Quad-Copter.

The performance of Ad-hoc network was evaluated using test bed method. Ad-hoc network was implemented using N-Raspberry pi 3 (Rpi 3) microprocessor, using their built-in Wi-Fi and a laptop as a Monitor unit. Each device in the proposed prototype system had used Optimized Link state Routing OLSR as routing protocol.

Ad-hoc network was evaluated for three scenarios that are; evaluating the configuration of Ad-hoc network, evaluating OLSR data forwarding over 1-hop / multi-hop and finally evaluate multi-hop mechanism in Ad-hoc networks.

The results shows that the routing protocol used in the implemented network can find a path for 1-hop and multi-hop and use that path to stream a video with acceptable jitter.

***Index Terms*— Quad-copter, UAVs, Ad-hoc network, Raspberry Pi 3, OLSR protocol.**

I. INTRODUCTION

Mobile Ad-hoc Networks MANETs which are mobile, rapid-deployed and dynamically changed topology had provided flexibility in establishing communications in many applications, such as military, emergency, disasters and so on.

Ad-hoc networks are wireless, infrastructure-less, self-configured and networks consist of N-nodes, each of them is equipped with a wireless interface-Wi-Fi, Bluetooth, Zigbee, etc. [1].

Each node in Ad-hoc network may act as source/destination or router [2] with limited range, grouping 'N' of these nodes can lead to more range that can be used in a variety of applications.

The main challenges of Ad-hoc networks are the dynamic topology and wireless communication characteristics, which make the operation of finding and establishing a path between any two nodes in the network as a big challenge.

Routing protocols developed for MANETs must adapt with the limited resources and dynamic topology of its nodes.

Ad-hoc routing protocols can be classified into three main categories, they are; Reactive (on-demand) routing protocols, examples are, AODV, DSR, etc., Proactive or table-driven routing protocols such as, DSDV, OLSR, etc. and finally Hybrid routing protocols that combine features of both reactive and proactive protocols, as an example is ZRP [3],[4],[5].

The proposed prototype system used Optimized Link State Routing OLSR protocol which is a proactive protocol that uses link state packet forwarding. In this protocol, the optimization processes are achieved by reducing the number of forwarded (flooded) packets by selecting Multi Point Relay (MPR) and reduce the size of control packets. Figure (1) shows the MPR nodes [4].

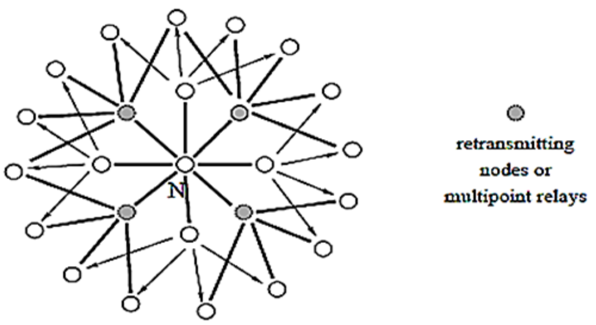


Figure 1. MPR nodes [4]

MPR nodes are calculated and selected from the set of 1-hop neighbors of the MPR selector node that have symmetric (bi-directional links with its MPR selector node interfaces).

OLSR protocol useful in dense-high dynamic topology changed networks and produce less delay than reactive protocols in finding and establishing paths because routes are stored in routing tables in each node [4], but it has a drawback in the complexity and usage of storage units.

Quad-Copter had become one of the hot topics these days. The interesting in designing and controlling of Quad-copter is increased since the revolution in electronics and due to its flying stability Drones had used in a very wide range of applications especially in ones where human interfere is dangerous and costly. Such applications are military, natural disasters, big woods fires and so on.

In the proposed prototype system here, the scenario needed to implement an ad-hoc network to stream video for long distances over multi-hop. The proposed prototype system can be developed to be used in a variety of applications, such as monitoring enemy borders in wars, in wild-wood fire-fighting, in surveillance and so on. The video streaming is done using a pi-camera mounted on a Quad-Copter that can cover more range than ground-fixed cameras.

II. RELATED STUDIES

Ad-hoc network had been increasingly interested in recently due to its characteristics, such as rapid-deployment and cost-effectiveness that make ad-hoc networks very useful in situations where normal infrastructure networks are infeasible [2].

In [6], Parmesan et al. had proposed SVANET system for the purpose of forwarding events of high ways such as accidents, heavy traffic or blocked roads.

Many researchers had proposed papers in surveying, designing and developing many algorithms to control Quad-copters. In [7], Matt et al. had designed small UAV and choose Quad-copter as an experimental platform. In [8], Anton and Bai had implemented a project that uses Quad-Copter for video monitoring for surveillance. Some other authors had surveyed the design and development of Quad-Copter and its controlling algorithms [9], [10], [11], [12].

In the subject of using Quad-Copter and Ad-hoc network, that both share the same characteristics that make both technologies suitable for critical and emergency applications, researchers and students had designed many systems and projects that use Quad-Copter with Ad-hoc network mechanism in search and rescue operations, such as in [11] Carlos et al. had presented an emergency rescue system using Quad-Copter connected to emergency center via ad-hoc network. In [13] Yixin et al. had designed a system using Quad-copter with Ad-hoc network to fight-fire in big woods in the United States.

III. IMPLEMENTATION AND TESTING OF AD-HOC NETWORK

In this paper, Ad-hoc network was implemented with three-nodes (one-lap top as a Monitor and two-Rpi 3, with one of the Rpi 3 mounted on a Quad-Copter).

Raspberry Pi 3 is a single board microcomputer, with built-in Wi-Fi and Bluetooth. Figure (2) illustrates Raspberry pi 3 and its basic components [14].

Figure (2) Raspberry Pi 3 [14]

Quad-Copter frequently called Drone that stands for Dynamic Remotely Operated Navigation Equipment [12] with the ability of vertical-take-off-and-landing, stability, simplicity in design, cost-effectiveness, and maneuverability had used in a variety of applications.

The flying of Quad-Copter can be controlled by controlling the speed of two or of its four-rotors to perform its basic motions (hovering, take-off and landing, moving forward and backward and turning left or right).Figure (3) illustrates the Quad-Copter and its basic components [7],[10],[11].

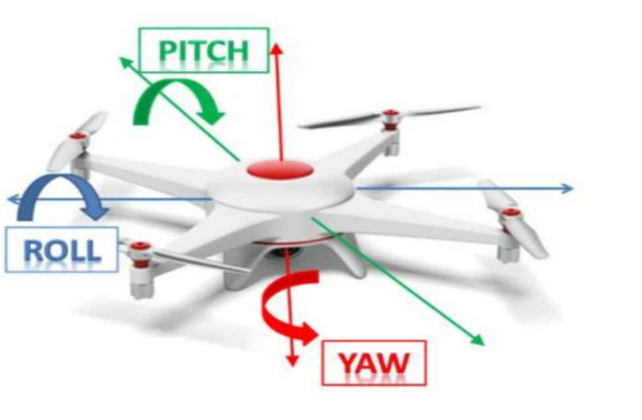


Figure (3) Quad-Copter Architecture [12]

The camera used in the proposed system is Pi-camera-v2 released by Raspberry Pi foundation; it is small light-weight with 8-megapixel resolution and supports the latest version of the Raspbian operating system. It doesn't need additional software to define it [13].

A. Ad-hoc Network Configuration

Figure (4) illustrates the proposed prototype system that was implemented using Quad-Copter and Raspberry Pi 3. This system can be developed to be used in many applications.

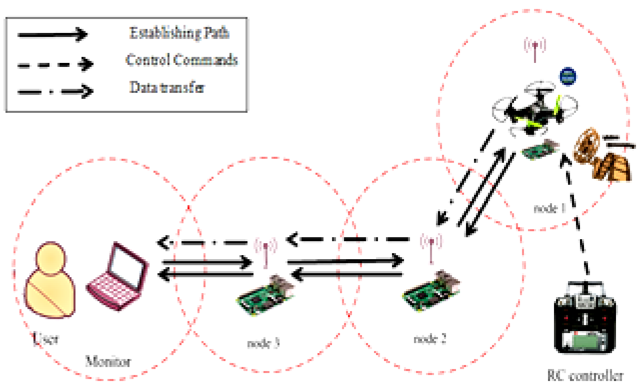


Figure (4) Proposed Prototype System

As shown in figure (4) Rpi 3 with pi-camera was mounted on a Quad-Copter and stream video to the Monitor over multi-hop strategy.

Ad-hoc network was implemented using hardware listed in Table (1).

Table (1) Network Devises Description

Device	Description
Raspberry Pi 3	Used as a node in Ad-hoc network with OLSR routing protocol
Quad-Copter	One of Rpi 3 with the camera was mounted on it to stream video to the destination node (Monitor)
Laptop	Used as Base-Station or Monitor to receive a video stream from a source node
Pi-camera	Used to record the video stream

The software required to configure Ad-hoc network is:

- Raspbian operating system was installed on each R pi 3, and Linux-Mint on the Monitor device.
- Additional programs (OLSR and mplayer) are installed on each node for the purpose of implementing and testing the different scenarios of Ad-hoc network.

In this paper, three scenarios were considered and tested using test bed method, which is:

i – Building Ad-hoc network among the four-nodes (one-laptop and three-Rpi 3) and testing the network's configuration.

ii – Evaluating the performance of OLSR protocol in finding a path from the source node to the destination node in 1-hop and 2-hop routing.

iii – Examining the network performance by streaming video over Ad-hoc network over 1-hop and 2-hop.

B. Ad hoc Network Implementation

To build Ad-hoc network among the nodes of the proposed prototype system, each node was set with ad-hoc mode, static IP address and host-name, as listed in Table (2).

Table (2) List of Static Settings of Implemented Ad-hoc Network

Node	Host-Name	IP address	Sub-net mask
Node 1	Pi 1	192.168.3.101	255.255.255.0
Node 2	Pi 2	192.168.3.102	255.255.255.0
Node 3	Pi 3	192.168.3.103	255.255.255.0
Node 4	ThinkPad	192.168.3.104	255.255.255.0

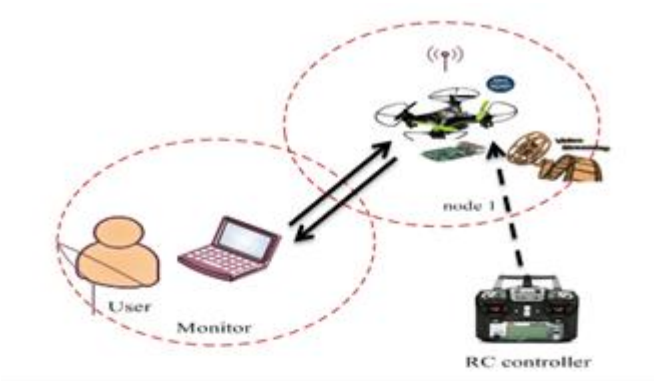
- In the proposed prototype system the ad-hoc network was configured depending on the built-in Wi-Fi of the Rpi3.

Figures (5) illustrate three different scenarios of the ad-hoc network;

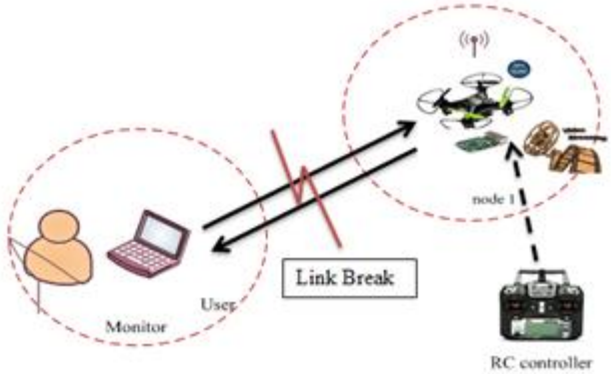
Figure (5-a) node-1 and Monitor see each other directly.

Figure (5-b) node-1 and Monitor moved out of the range of each other's (i. e. link break).

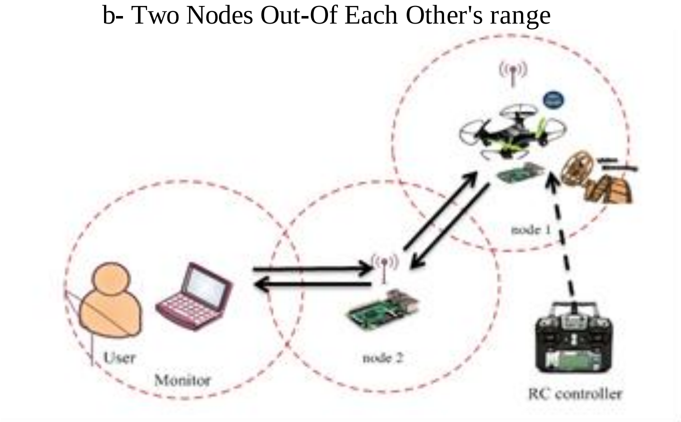
Figure (5-c) node-2 is added to forward data from node-1 to Monitor over 2-hop



a- Two Nodes within Each Other's Range



b- Two Nodes Out-Of Each Other's range



c- Node-2 Bridge Between Node-1 and Monitor

Figure (5) The Three Scenarios of Ad-Hoc Network

Network configuration and testing was done by using commands "iwconfig" and "ifconfig", showing that the standard of Wi-Fi is IEEE 802.11, the Extended Service Set IDentifier (essid= Ad_hoc) and the mode is ad-hoc with frequency= 2.405 GHz and transmit power= 15 dBm.

To do that each node has bi-directional (symmetric) link connectivity to other nodes use "ping" (Packet InterNet Groper) command among the nodes of the network.

C. Configuring OLSR Protocol

For each node in the network, OLSR protocol was installed on. To start the protocol the following changes were done;

- Debug level to 1
- IpVersion 4 # set by default

- Add the wireless interfaces (wlan0 for Rpi 3 and wlp3s0 for the laptop) for each node within the protocol's code lines.

When startup each node in the network and starting OLSRD protocol operation [16], it will start searching for 1-hop and 2-hop neighbors by sending "Hello" packets periodically to build the routing table [16].

To test path establishment among the nodes of the network, the three scenarios shown in figure (5) were implemented and tested.

Figure (6) shows the "Hello" packet testing where the IP addresses of 1-hop and 2-hop neighbors are listed.

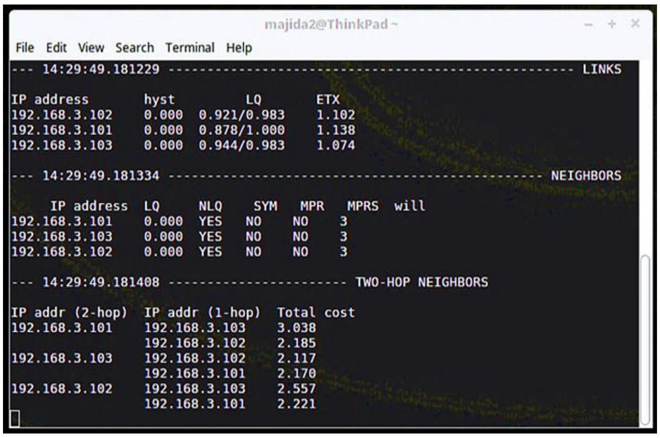


Figure (6) OLSRD "Hello" Message Testing

Figure (7-a), shows the result of "traceroute destination IP address" for 1-hop where the two nodes see each other's directly (for a scenario of figure 5-a), and figure (7-b) illustrates the 2-hop route between the two nodes (for scenarios of figure 5-c), where packets were forwarded to destination across node-2.

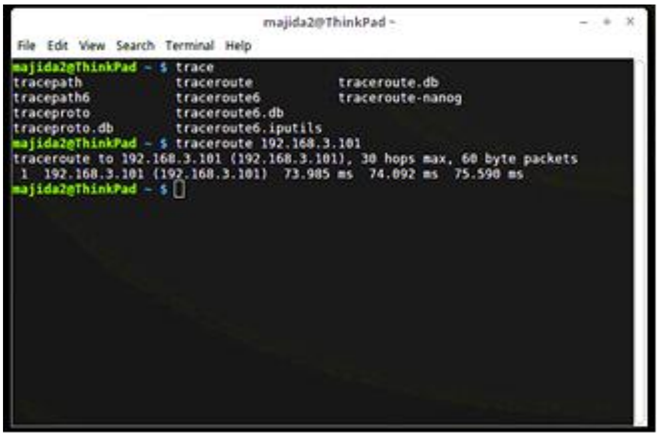


Figure (7-a) Traceroute for 1-hop

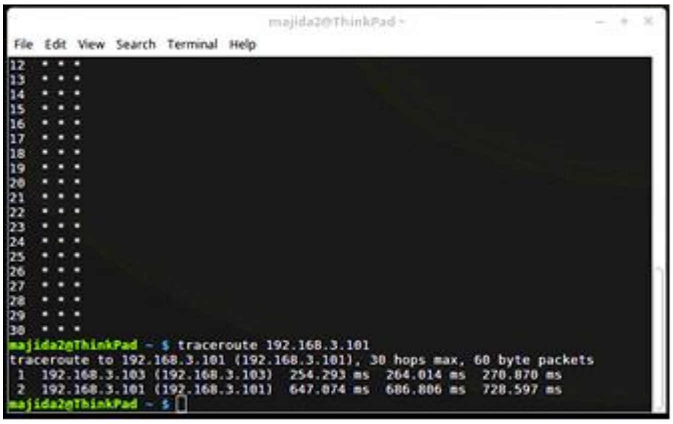


Figure (7-b) Traceroute for 2-hop

IV. Testing Video Streaming

To test the performance of Ad-hoc network for video streaming over N-hop, by sending video from Rpi 1 (i.e. node-1) to the laptop (monitor) by using "mplayer" as a media player to send video stream.

Figure (9) shows the result of "jperf" tests for 1-hop video stream, where the two curves declares the jitter variation for 6sec. interval, and the other curve shows the bandwidth stability over same interval and same distance video stream.

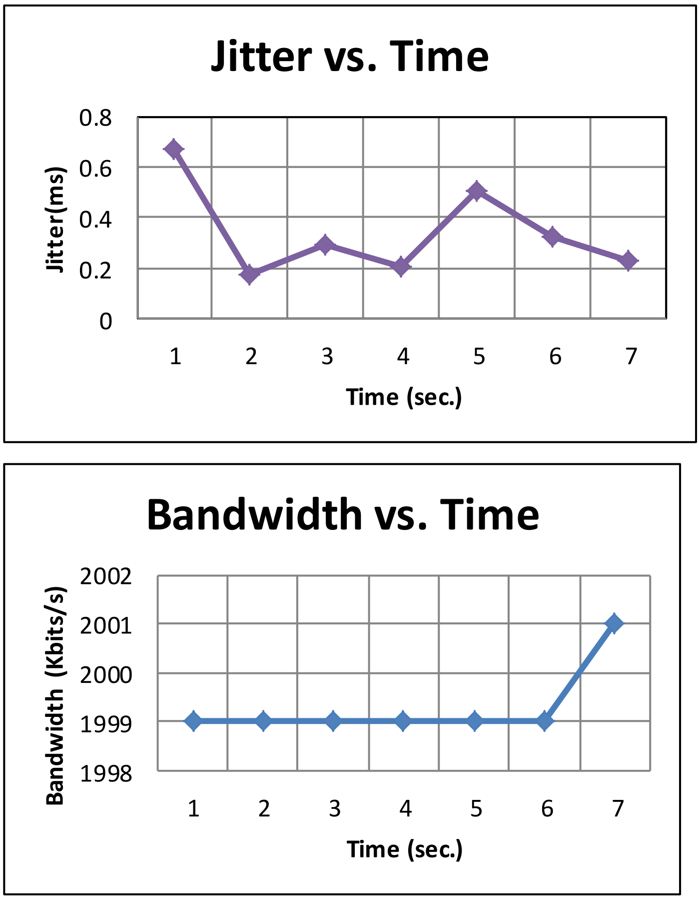


Figure (9) The Relationship for Bandwidth and Jitter vs. Time

V. Conclusion

As a result of implementing different scenarios of Ad-hoc network, with 1-hop, no-path, and 2-hop (between Node-1 as source and Monitor as destination).The results-obtained proved that Rpi 3 with OLSR as routing protocol can be used to implement Ad-hoc network, and test that network through several tests shown in this paper.
The tests included: testing for Ad-hoc network configuration using the built-in Wi-Fi of Rpi 3, testing for self-healing by adding an additional node and finally testing the performance of the network to stream video over the ad-hoc network with 1-hop.

References

[1] M. Dipobagio, "An Overview on Ad Hoc Networks," Inf.Fu-Berlin.De, pp. 1–9, 2009.

[2] P. Kuosmanen, "Classification of Ad Hoc Routing Protocols," pp. 1–13, 2002.

[3] P. Jacquet, P. Muhlethaler, T. Clausen, A. Laouiti, A. Qayyum, and L. Viennot, "Optimized link state routing protocol for ad hoc networks," Proceedings. IEEE Int. Multi Top. Conf. 2001. IEEE INMIC 2001. Technol. 21st Century., pp. 62–68, 2001.

[4] S. Dhenakaran and a. Parvathavarthini, "An Overview of Routing Protocols in Mobile Ad-Hoc Network," Int. J. Adv. Res. Comput. Sci. Softw. Eng., vol. 3, no. 2, pp. 251-- 259, 2013.

[5] C. Cambra, S. Sendra, J. Lloret, and L. Parra, "Ad hoc Network for Emergency Rescue System based on Unmanned Aerial Vehicles," Netw. Protoc. Algorithms, vol. 7, no. 4, p. 72, 2016.

[6] P. Sahoo, M.-J. Chiang, and S.-L. Wu, "SVANET: A Smart Vehicular Ad Hoc Network for Efficient Data Transmission with Wireless Sensors," Sensors, vol. 14, no. 12, pp. 22230–22260, 2014.

[7] Parker Matt, Robbiano Chris, Gerad Bottorff, "Quadcopter," , Dep. Of Electrical and Computer Engineering, Colorado state University,2011.

[8] A. Nakazawa and B. X. Jin, "Quadcopter Video Surveillance UAV," p. 9, 2013.

[9] Deepak B.B.V.L and Pritpal Singh, "A survey on design and development of an unmanned aerial vehicle (quadcopter)," Int. J. Intell. Unmanned Syst., vol. 4, no. 2, pp. 70–106, 2016.

[10] S. Gupte, P. Mohandas, and J. Conrad, "A survey of quadrotor unmanned aerial vehicles," Conf. Proc. - IEEE SOUTHEASTCON, 2012.

[11] I. JEFFREY, D. Isleifson "Implementation of a Quadcopter Flight Controller with Obstacle Avoidance and Navigation," 2017.

[12] P. Parihar, P. Bhawsar, and P. Hargod, " Design & Development Analysis of Quadcopter," vol. 5, no. Vi, p. 2320, 2016.

[13] Y. Gu, S. Fu, Y. Wan, and H. Zhang, "Drone-carried Ad Hoc WiFi system for Use in Fighting Wildfires," p. 76207, 2003

[14] Raspberry Pi Foundation, "Raspberry Pi 3 Model B Technical Specifications," Uf.Farnell, p. 8, 2016.

[15] Raspberry Pi Foundation URL / https://www.raspberrypi.org/documentation/hardware/camera/README.md

[16] OLSR Organization URL/ http://www.olsr.org/mediawiki/index.php/Main_Page.

