International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8 Issue-4, November 2019

# Performance of 4G-LTE Communication and Navigation System in Blended Wing-Body UAS

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***Abstract*: *In vision of searching for the right Unmanned Aerial System (UAS) for a specific mission, there are multiple factors to be considered by the operator such as mission, endurance, type of payload and range of the telemetry and control. This research is focusing on extending control range of the UAS by using 4G-LTE network to enable beyond-line-of-sight flying for the commercial UAS. Major UAS such Global Hawk, Predator MQ-1 are able to fly thousands of kilometers by the use of satellite communication. However, the satellite communication annual license subscription can be very expensive. With this situation in mind, a new type of flight controller with 4G-LTE communication has been developed and tested. Throughout the research, blended-wing-body (BWB) Baseline B2S is used as the platform for technology demonstrator. Result from this analysis has proven that the proposed system is capable to control a UAS from as far as United Kingdom, with a latency less than 881 ms in average. The new added capability can potentially give the commercial UAS community a new horizon to be able to control their UAS from anywhere around the world with the availability of 4G-LTE connection.***

***Keywords*: *4G-LTE connection, UAS, flight controller, BWB.***

## I. INTRODUCTION

The Unmanned Aerial System (UAS) industry has seen a massive growth throughout the last five years. As mentioned in [1], "*UAS have the advantage of being rapidly deployable, able to cover a greater area, less affected by the terrain and they use the spectrum more efficiently*". In searching for the right UAS for specific mission, several multiple factors need to be considered by the operator as a baseline such as mission, endurance, type of payload and also the range of the telemetry and control. However, most available commercial UAS today are operated manually and within close proximity of the pilot. This significantly limit the scalability of solutions and is seen as the major road block to further growth of the industry. In view of this limitation, many large scale applications such as delivery, remote inspection, security and surveillance cannot be deployed efficiently.

As researchers in the UAS community, Flight Technology and Test Center (FTTC) and AICAD Aero Engineering LLP have been constantly innovating a better platform to automate and scale UAS operations, and aspiring to enable deployment of UAS beyond visual line-of-sight. Getting real time control of unmanned aircraft over a long range communication such as 4G-LTE with live video, telemetry and flight are crucial to operations. On the high scale, UAS such as Global Hawk and Predator MQ-1 have been able to fly thousands of kilometers by using satellite communication (SATCOM), usually via the L- and C-band spectrum. Unfortunately, not everyone is able to get their hands on satellite communication annual license as they are deemed to be very expensive to subscribe. With this in mind, this research has gone above and beyond to develop a new type of flight controller with a new added capability - the ability to support 4G-LTE communication. Mobile networks such as 4G-LTE network could support UAS applications to enable beyond the line-of-sight limitations [2]. Command and control (C2) is one of the areas where 4G-LTE could become an ideal solution [3]. The comparison of UAS communication data links on applicability, advantages and disadvantages are addressed in [4], which is very useful to better understand the generation of mobile communication network.

## II. THE PROPOSED SYSTEM

A blended-wing-body (BWB) platform, known as Baseline B2S, is used in this study for the technology demonstrator of the proposed 4G-LTE communication and navigation system. It is shown in Fig. 1. The proposed system is called Falco-X1 Advance Autopilot flight controller that has been developed in-house and programmed at FTTC in UiTM Shah Alam, an aerospace engineering center of excellence under the Faculty of Mechanical Engineering.

The Baseline B2S platform is designed based on the BWB technology that is widely known for efficient aerodynamics. Based on previous studies at FTTC, the lift-to-drag ratio for BWB aircraft ranges from 14 to 25 for small-sized UAVs.

Manuscript published on November 30, 2019.
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It is generally a tail-less aircraft incorporating a set of elevons and electric motor-propeller combination to control and navigate its flight. The Falco-X1's flight controller, as illustrated in Fig. 2, will control each servo of the two elevons and speed of the single electric motor that spins the propeller.

Because of its tail-less design, the Baseline B2S is inherently dynamically unstable. Hence, the Falco-X1 flight controller must be able to automatically stabilize the Baseline B2S during flight as a mandatory requirement before it can be allowed to further navigate the aircraft [5]-[6].

Normal flight controller system such as Pixhawk (by 3DR), Ardupilot APM and CC3D can be connected to the 2.4 GHz radio receiver to receive flight navigation commands from the ground. Furthermore, the flight controller is also connected to 5.8 GHz radio transmitter to transmit video, and either 433 or 915 MHz radio transceiver to transmit aircraft telemetry and flight navigation data. The transceiver also enables unmanned aerial vehicle (UAV) to receive new waypoints or commands during flight. The radio frequencies, however, are limited to a certain range (i.e. between one to five kilometers) within the operator's line-of-sight. Meanwhile, the proposed Falco-X1 system is a solution to this limited radio communication range because it uses 4G-LTE signal from local network provider. It also provides additional mean of determining the location of the UAV should any of the Falco-X1's internal and external GPS modules be affected by weather. As highlighted in [7], "*4G LTE provides superior position location capabilities is the fact that it uses a separate technology standard in the radio uplink than from the radio downlink, making it easier to distinguish between signals coming from the mobile device than from those coming from the cell tower base station*" [7].

The main goal to develop the Falco-X1 flight controller is to integrate a flight computer to stabilize, control and navigate UAV with 4G-LTE communication to compliment or replace conventional radio receiver, transmitter and transceiver that are usually installed on UAV with automatic flight capability as depicted in Fig. 3. Falco-X1 flight controller is not limited by the law of processing power or small amount of memory that is typically found in microcontrollers such as Arduino's PX4-based chipset. This is because it is basically a palm-sized computer with a high-speed processor and also large memory running on Linux program codes. The full Linux environment provides incredible networking capabilities on virtually any software such as Mission Planner and Ground Control Station (GCS). This system not only ease the connectivity to on-board modem that receives and transmits 4G signal from/to nearby base transceiver station (BTS) but it is also able to secure the connection between itself (i.e. on-board UAV) and its ground control station using the internet protocol (IP). The IP-based communication for UAS has now become possible and hence creating an unlimited possibility on the capability of a UAS. In the era of Internet-of-Things (IoT) these days, connectivity has become an essential aspect for any system development including its subsystems. The software-based program codes in Falco-X1 can process data from other external on-board components such as video camera. However, for the purpose of this paper, the additional capability will not be tested and analyzed just yet.

**Fig. 1. BWB Baseline B2S**

**Fig. 2.Falco-X1 Advance Autopilot flight controller**

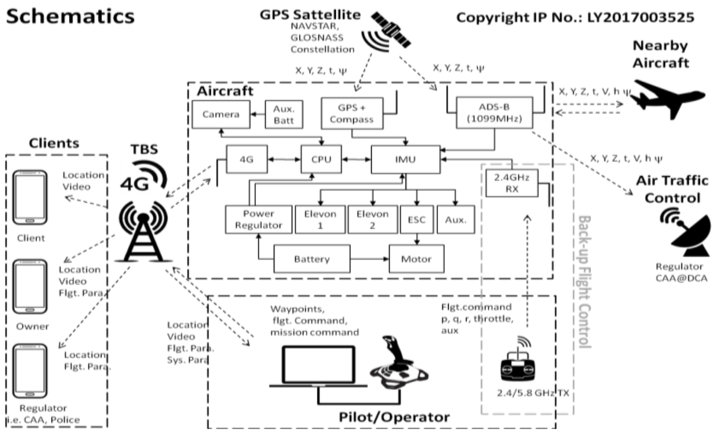


**Fig. 3.UAS network connection**

The Falco-X1 is controlled by the Ground Control Station (GCS) via internet cloud. A network tunneling connection is created and established between GCS and flight controller to enable data transfer and exchange.

The tunneling will enable data transfer by a secure network over public network such as the internet. Fig. 4 visualizes the connection between the GCS and Falco-X1. Most typical firewall of a network only allows outbound of data but does not allow inbound of data. This will limit the communication between two different networks.

## III. TEST METHODOLOGY

The testing of the proposed Falco-X1system is carried out in two phases. Phase one is intended to test the reliability of the communication setup between the GCS (source) and the BWB B2S (target). Multiple locations from where the source is connected from are chosen. In this testing phase, the source will establish a connection to the target from three different locations, which are Bukit Jalil, Kuala Lumpur (19 km), Kota Baru, Kelantan (397 km) and also London, United Kingdom (10,505 km). The target remains in the same location in Shah Alam.

Meanwhile, phase two of the testing process is designed to evaluate every connection on the communication latency. A specific utility is used to trace the exact taken path by the data packet on its way to the designated target from the source. In order to trace the followed route from the source to the target, at the command prompt, the "tracert" command is typed. The data packet will find its way to the target. Each time it reaches the router on its path, it will report back the information about the router such as the IP address and the time it took between each hop.

The latency is timed from the pilot's input at the source up to the target reaction. Both pilots are using the same type of joystick controller, which is the Logitech 3D Joystick. Two sets of results are obtained by assigning two pilots in different locations from the BWB B2S. The first set is conducted with the pilot located in London while the second test is conducted between a pilot and BWB B2S in Shah Alam. The results of all test are shown and discussed in the next subsection.

## IV. RESULTS AND DISCUSSION

The first set of results shown in Fig. 5 indicates that it takes 14 hops for the data command to reach the BWB B2S in Shah Alam from London. In contrast, as depicted in Fig. 6, it only takes six hops for the data command to reach the BWB B2S when it is being locally transferred from a GCS. The distance between the target and the source determines how many hops it will take during the data transfer. The latency test results are recorded and plotted as presented in Fig. 7. Overall, the test is done five times so that a pattern of results can be plotted and observed. Two sets of results are obtained through the latency test. It is observed that the average latency between London and Shah Alam is 881 ms whereas the average latency within Shah Alam is 311ms.

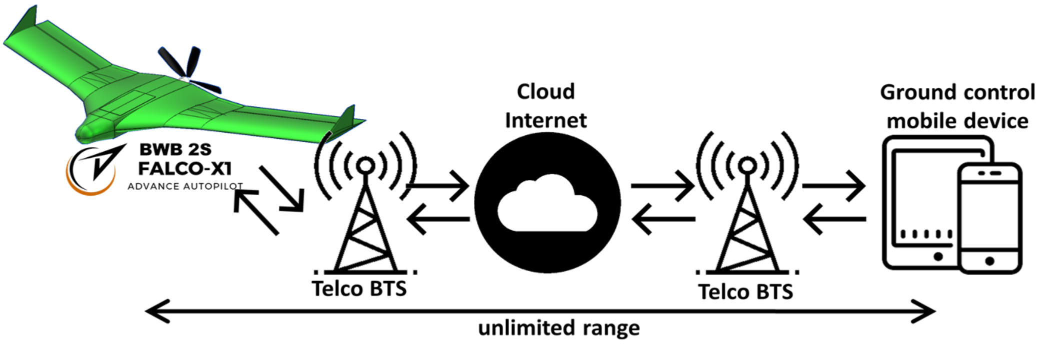


**Fig. 4. Network tunneling**

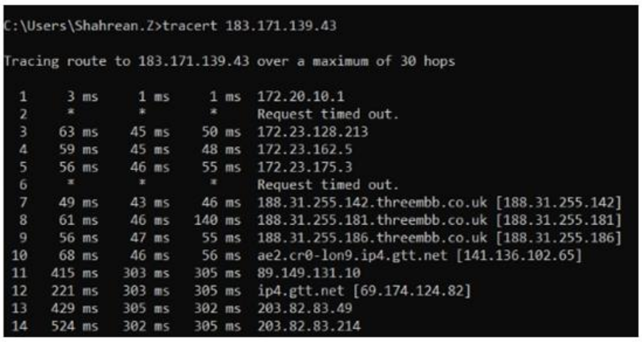


**Fig. 5. Routing from London to Shah Alam**

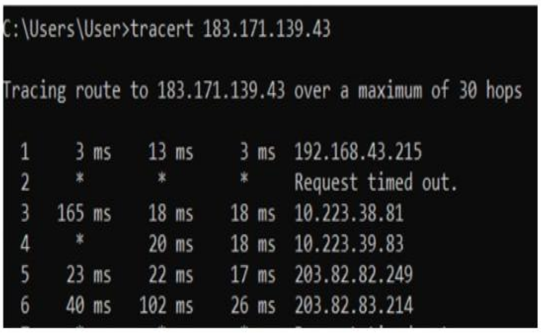


**Fig. 6.Routing within Shah Alam**

*Retrieval Number: D9910118419/2019©BEIESP*
*DOI:10.35940/ijrte.D9910.118419*
*Journal Website: www.ijrte.org*



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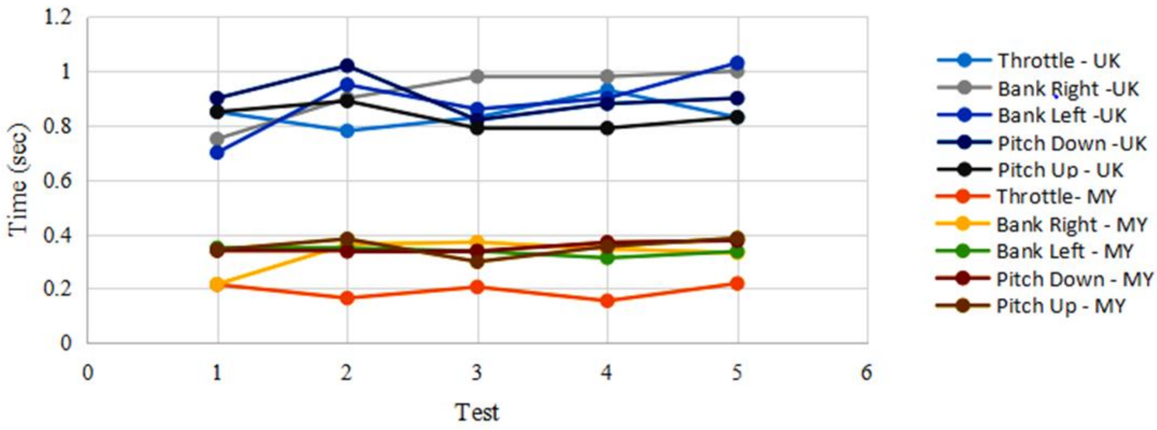


**Fig. 7. Latency test result**

## V. CONCLUSION

As a conclusion, UAV control by using 4G-LTE network is possible despite far distance between pilot and the aircraft. As predicted, there are latency differences between a pilot who navigates from London compared to a pilot navigating just a few meters away from the BWB B2S. Although there is no visible difference in terms of the servo-elevon response time between the two location cases through visual observations, the average measured difference is 570 ms between both cases or roughly half a second. In other words, BWB B2S's elevon will respond around half a second later when it is controlled from London than its own home in Shah Alam. In the future, a proper method to measure the latency of the modules using a more accurate device or application should be implemented. In addition, instead of measuring the latency of the modules, the latency of video and data feed should also be measured.


## ACKNOWLEDGMENT

This research is a part of the project that is funded by the BESTARI PERDANA Grant 2018 (600-IRMI/PERDANA 5/3 BESTARI (047/2018)) and also the SINERGI Grant 2019 (600-IRMI/SINERGI (001/2019)). The authors would like to express gratitude to Universiti Teknologi MARA's Research Management Centre, Faculty of Mechanical Engineering for the grant money and various supports. Moreover, our special thanks are dedicated to Mr. M. Zulhairi M. Nor, Mr. Amirul S. A. Rushdi, Mr. Amirul A., Ms. Nur F. Salleh and also other research students under the Aviation Research Group, Flight Technology and Test Centre (FTTC), Universiti Teknologi MARA, Shah Alam, Malaysia.


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**Shahrean Zainurin** has obtained his diploma degree from the Universiti Kuala Lumpur-Malaysian Institute of Aviation Technology in Aircraft Maintenance Technology (Manufacturing). He is pursuing his Master of Science (MSc) in Mechanical Engineering at Universiti Teknologi MARA (UiTM) Shah Alam, Malaysia. With 15 years of experience in the aviation industry, mainly within the pilot training and flight simulation industry, his research has been focused on the UAV avionics system and flight simulation under the collaboration with the Flight Technology and Test Center (FTTC) of UiTM Shah Alam. To date, under the flagship of FTTC, his team has won 2nd place in the My DroneX University Competition for NAMTOR 3: Medical Drone project and a Gold Award at Pencipta 2019 for Blended-Wing-Body Unmanned Aerial Vehicle with 4G Internet-based Command, Communication and Navigation research study. He has been granted the status of Member with Royal Aeronautical Society (RAeS) in United Kingdom since 2019 and is currently working as Senior Flight Simulator Engineer at Ryanair, United Kingdom.

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