TESTING COMMUNICATION SYSTEMS IN UNMANNED AERIAL VEHICLES

Testing Communication Systems in Unmanned Aerial Vehicles

INTRODUCTION

An increasing number of components within Unmanned Aerial Systems (UAS) or Unmanned Aerial Vehicles (UAV) used by the military and others are now being connected via Ethernet. This connectivity includes communication between internal components, as well as over wide area wireless networks with ground stations, satellites and even other aerial vehicles. UAVs can be fixed or rotary-wing vehicles, with a wide variety of configurations such as High-altitude long-endurance, Medium-altitude long-endurance, Tactical, Mini, and Micro. And these UAVs are being deployed extensively by various defense forces around the world for intelligence, surveillance, reconnaissance and assault applications. There are also important and growing scientific research and commercial applications for UAVs.

UAV Data Link Systems

Of the many different sub-systems within UAVs, the communications or Data Link sub-system is one of the most critical. A primary function of the Data Link system is to consolidate data from the various sensor payloads such as infrared and thermal imaging cameras, targeting systems, and flight telemetry systems, and relay them to the operations control center consuming the information. Communication between these payload sensors and control centers is often achieved via a Satellite Communication (SATCOM) link.

SATCOM links present many challenges to reliable communications. For example, they can have low available bandwidth, and during some operation periods they can experience a high degree of interference from weather conditions or intentional jamming, resulting in intermittent data corruption. Also, critically important to consider, is that these SATCOM links have very high latency due to their distant location in orbit. Latency due to this distance can be up to 1.3 seconds for a geo-stationary satellite. Factoring in additional processing (e.g., encryption/decryption), queuing, and switching delays, the total Round Trip Time (RTT) can total 5 seconds, or even higher. This extreme latency has a profound effect on communications protocols and end-user application performance and must be understood and evaluated prior to deployment.

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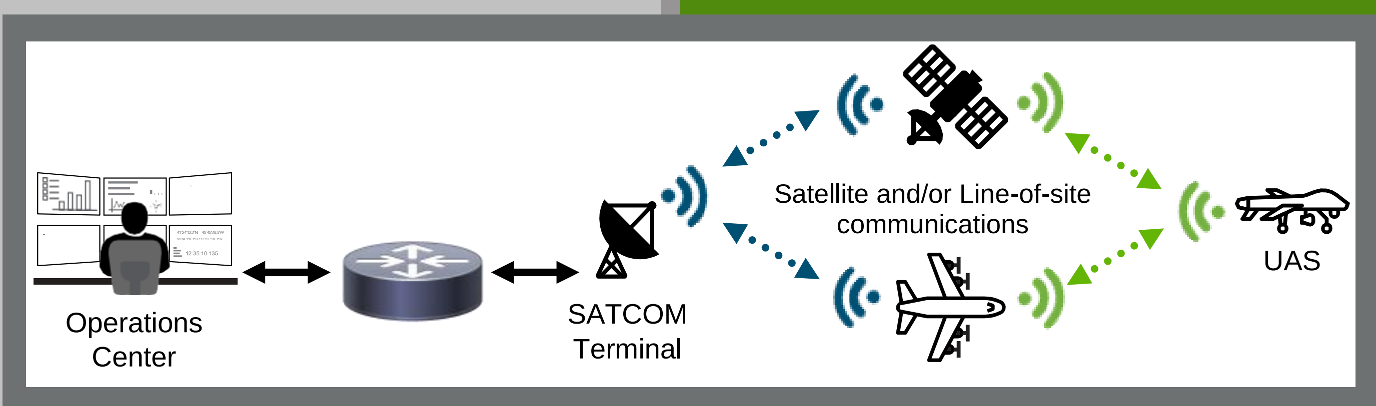

Figure 1: Example UAV deployment with combined Line-of-Site and Satellite communication paths

Communication Protocols

In environments like those described, there are several key requirements to consider for high performing communication protocols.

1 RELIABLE DATA DELIVERY

This includes the ability to detect errors or lost data, and then handle this situation in a well-defined and consistent manner to keep higher layer applications stable. Examples include requesting data retransmission from the sender, and/or informing the higher layer applications when integrity issues occur so that corrective action can be taken.

2 MINIMAL PROCESSING OVERHEAD

This characteristic is critical for achieving maximum throughput performance in real-time.

3 HIGH LATENCY

More specific to the applications we are focused on here, the protocol must be capable of operating effectively in high latency environments.

TCP and UDP are examples of widely used data transport protocols. Flow control, congestion control and acknowledgement algorithms are built in. These algorithms work well on low-latency terrestrial networks, however on data links where there is packet loss combined with significant RTT or large delay variation, these protocols, especially standard implementations of TCP, can become problematic as they assume that any loss or large delay variations are caused by congestion. This can cause data throughput performance to decrease rapidly and some applications may even cease working and out-right fail.

Test Considerations

The only way to improve system stability, reliability and maximize performance under these challenging "real-world" conditions of high variable latency, intermittent link loss, and limited bandwidth is to test under these same conditions in the lab, earlier in the design and validation phases of development.

Re-creating these real-world conditions in the lab is achieved by utilizing a Network Impairment Emulator (NIE), sometimes also called a WAN Emulator. A NIE works by transparently sitting in-line with the devices or systems under development and evaluation. The NIE emulates the real-world network by introducing latency and impairments and restricting bandwidth in order to empirically evaluate a device, protocol, application or system's performance and gather end-user experience measurements under non-ideal conditions in the lab.

By developing and testing with real-world conditions in the lab, earlier in the development lifecycle, not only is risk greatly reduced, but applications and protocols can be more effectively tuned to improve performance in terms of faster response times, increased throughput, better video quality, and a much more stable and reliable platform under intermittent negative conditions such as temporary link loss which are present in SATCOM and line-of-site communication links. This prevents you from being caught off guard dealing with unexpected issues once you deploy your solution in the post-production field. All of this results in getting to market faster with higher performing solutions.

In addition to pre-deployment testing, NIEs can be used for post-deployment testing as well. By bringing real-world conditions to the lab, it becomes easier to reproduce post-production issues in the lab. In turn this improves Mean Time to Repair (MTTR) and creates a more effective methodology for proving and qualifying a possible fix to the original problem prior to performing field upgrades.

The Network Impairment Emulator emulates the real-world network by introducing latency and impairments and restricting bandwidth.

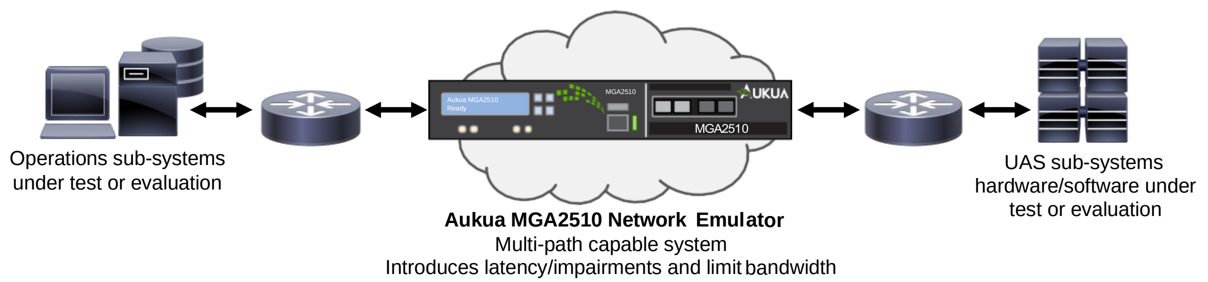

Figure 2: UAV lab-based testbed utilizing Aukua MGA2510 Network Impairment Emulator

Choosing a Network Emulator Solution

It is important to note that for optimal testing of mission critical systems, you cannot choose any Network Impairment Emulator. Most of the NIEs on the market are software-based and simply cannot provide the realism and repeatability required to successfully unlock the benefits highlighted earlier.

1 PERFORMANCE

The NIE must have a higher degree of performance than the device or system under test which can only be offeredbyatruehardware-based(e.g., FPGA based) NIE system. You cannot trust any test results if, for example, the NIE has lower throughput performance than the device under test and packets are unexpectedly dropped. You do not want the NIE to be the cause of any issues discovered during testing. Software-based NIE's have restrictions on bandwidth that they can handle, limited packet sizes that can be processed, and their performance and accuracy even decrease as impairments, packet filtering and other functions are enabled.

2 PRECISION

The higher the precision in controls provided by a NIE, the better the visibility into issues it can provide. With better visibility into what is going on in a testbed, issues can be diagnosed and resolved faster. Only hardware-based NIE systems can provide you the visibility that is needed for testing mission critical systems like UAVs. Software-based NIEs simply don't have the resolution needed for effective testing. Without precise control of latency, bandwidth and impairments, it becomes very difficult, time consuming, or impossible to accurately determine maximum tolerable latency or minimum viable bandwidth for example.

3 REPEATABILITY

Repeatability is key to any proper test methodology. If the NIE cannot provide repeatability, it becomes impossible to confirm if an issue has truly been resolved, or to know what caused an increase or decrease in performance of the device under test. Repeatability is also crucial for establishing baseline performance for regression testing from one firmware/ software version to the next.

Aukua Network Impairment Emulator Solution

The Aukua MGA2510 Network Impairment Emulator, with its hardware-based architecture and industry leading precision, is the ideal NIE for testing UAV systems, as it ensures the most realistic and repeatable test methodology.

Leveraging Aukua's NIE solution enables you to test under a wide variety of ideal to extreme negative network conditions. It allows you to control the amount of static latency, packet delay variation (PDV), bandwidth limits, packet loss, link loss or link flapping, bit errors and much more. You can also create symmetrical or asymmetrical network conditions, as well as static or dynamic conditions. This type of testing is simply not possible, in a cost-effective and repeatable way, in the post-deployment production environment.

Another important ability of the Aukua NIE solution is that it can emulate up to 16 unique "Network Paths" per direction. This means, you can classify traffic to a specific Network Path based on packet characteristics such as device or IP address, VLAN ID, TCP/UDP port number, protocol, Class of Service, or any other packet content, as well as on packet size. Each Network Path can have unique user-configured delay, loss, bandwidth, etc. conditions. This ability allows you to emulate different paths through a network (e.g., a primary direct line of site path or a secondary SATCOM path) where each path may have different available bandwidth, latency and impairment conditions. Also, this allows you to emulate traffic being treated differently based on Class of Service (CoS) values or Service Level Agreements. Lastly, this capability allows you to perform negative tests, targeting specific packets for impairment. For example, dropping a TCP acknowledgement packet to test the robustness of the protocol stack.

Test Applications Enabled with Aukua's Network Impairment Emulator

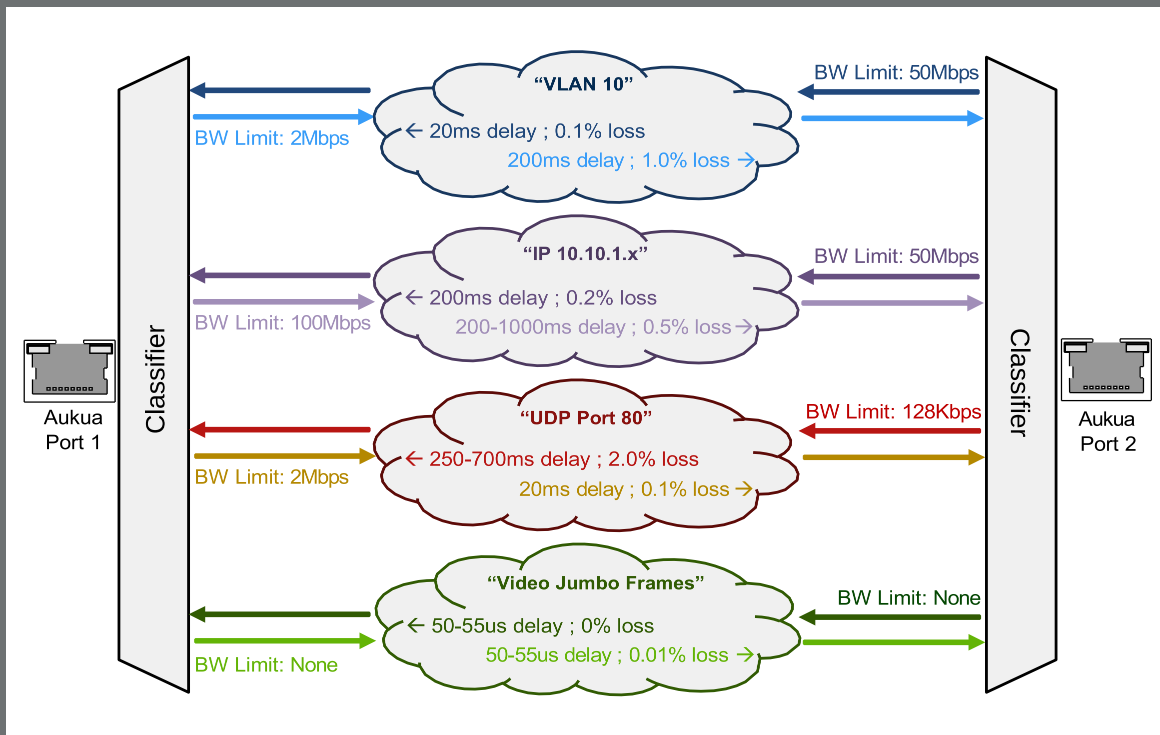

Figure 3: Logical view of Aukua MGA2510 emulating multi-path network with each path having unique asymmetrical bandwidth, latency and impairment conditions

- Characterize maximum throughput performance and empirically measure video quality or other sensor data delivered across various real-world network conditions
- Demonstrate and prove fail-over scenarios from primary to secondary communication links
- Determine maximum supported latency, and minimum viable bandwidth requirements while still maintaining acceptable performance
- Tune applications and protocol stacks to maximize performance under extreme network conditions
- Assess protocol and application stability under dynamic and variable network conditions with intermittent link loss, highly variable latency, or various bit error rate conditions
- Conduct proof of concept testing under real-world scenarios for rapid prototyping
- Reproduce post-production issues more efficiently by bringing real-world conditions back to the lab and proving a potential fix before deployment for greater confidence
- Discover how a system is impacted by intermittent negative impairment conditions

Aukua's MGA 2510 helps mitigate project risk and cost while simultaneously enabling you to develop more robust, superior-performing unmanned vehicles.

CONCLUSION

With Ethernet technology now actively being leveraged in unmanned, autonomous vehicles of all types, smarter test methodologies must be considered.

Specifically, if you are not considering the effects of delay, limited bandwidth and other network impairments early in your development and testing, you will be in for an unpleasant surprise once you start to deploy. For UAVs in mission critical situations, the difference between a robust, high performing vehicle and an inferior, poorly tested vehicle could be the difference between life and death for personnel in harm's way. An asset that provides inferior, incomplete or intermittent sensor data will directly hinder decision makers on the ground from making optimal, timely, life-saving decisions.

For these reasons, the traditional way of developing and testing in a pristine lab and only considering real-world network conditions after deploying in the field of operation is short sited, risky, time consuming, and costly. Thankfully this approach is now avoidable.

Aukua's MGA2510 helps mitigate project risk and cost while simultaneously enabling you to develop more robust, superior performing unmanned vehicles. In addition, with the MGA2510 you can resolve post-production issues faster and conduct rapid prototyping under realistic network conditions. Aukua can easily re-create real-world network conditions such as latency, asymmetric bandwidth limits, network congestion or other negative scenarios.

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