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Performance Evaluation of MPI-CDL Airborne Network in OMNET++

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Abstract

This paper briefly describes the Multi-Platform Image and Intelligence-Common Data Link (MPI-CDL) network architecture. Objective is to evaluate performance of MPI-CDL network protocol in a simulator for various performance measures like throughput, latency, jitter etc. We have selected OMENT++ for simulation and will try to simulate various operational scenarios of MPI-CDL network. This paper presents our initial finding and results for two scenarios of MPI-CDL networks i.e. one-to-one and one-to-many communication. Both scenarios were tested for 274Mbps data rates. For each data rate, we have tested different packet sending interval and observed that if we goes beyond a certain threshold than most of the packets get dropped at source MAC buffer. This may be due to some internal misconfiguration in OMNET++ and we will try to figure out its reason and solution.

Keywords: MPI-CDL, Network Simulation, OMNET++

INTRODUCTION

Standardization Agreement 4586 (STANAG 4586) is a NATO standardized protocol for the control of UAVs [1]. Its purpose is to promote interoperability in the control and communication with UAVs for members of NATO and Partners for Peace (Standard Interfaces of UAV Control System (UCS) for NATO Interoperability, 2007) [2]. STANAG 4586 has become a de facto standard on the UAV market.

Multi-Platform Image and Intelligence Common data link(MPI-CDL) systems are designed to transmit the imaginary and signal intelligence data at an aeronautical to ground line of sight(LOS) link [3]. With this technology, data can be transmitted at a distance of more than 200km up to 45 Mbps class. MPI-CDL networks are mainly designed for enabling real time communication among high speed UAVs and ground stations. Figure 1 shows that these networks are able to achieve maximum 45Mbps (uplink), 274Mbps (downlink) over distance of 293km.

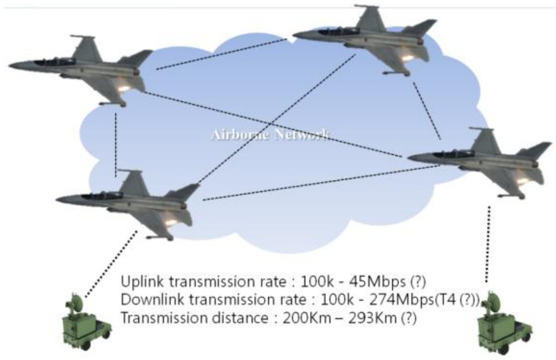

Figure 1. Multi-Platform Image and Intelligence-Common Data Link (MPI-CDL) Network.

K. J. Kwak et.al. present the concept of future airborne network and its challenges in [4]. A comprehensive survey on major challenges in UAV is presented in [5]. Many heterogeneous platforms are expected to work cohesively requiring high bandwidth and reliability to support its operation. They present a set of use cases to illustrate how high fidelity emulation can be used to evaluate new architectures and protocols in AN environment. Reliability transmission is a major concern and Jun Li et.al have evaluated packet delay in unmanned aerial vehicles (UAVs) with channel fading and unsaturated traffic scenarios [6]. In airborne networks, nodes are expected to move a particular pre-planned path so this information is utilized to develop a mobility aware routing protocol for backbone network [7]. Many civilian utility applications of UAV based public networks are proposed in literature e.g. forest fire, terrorist attacks, volcanic eruption, liquid and gas contamination etc [8, 9, 10]. To cope with emergency situations, a self-organizing mesh network of UAV is proposed in [11].

Our objective is to add security layer to MPI-CDL protocol and conduct performance analysis. Authors in [12] have developed a security simulator for airborne network i.e. airborne network security simulator (ANSS) but that is more focused on general airlines security. Simulation results of large scale airborne network has been presented in [13] using ns-3. A more general architecture of simulation environment for airborne networking is discussed in [14]. This work is mainly focused on building simulation setup for MPI-CDL in OMNET++. Once, we setup the environment then we can perform various experiments to improve its design and add security layer in future.

In real time networks operations, MPI-CDL has four possible scenarios as shown in Figure 2. In point-to-point scenario, one node in the network needs to communicate with single other nodes. In MPI-CDL network operational scenario, when a ground station want to send message to a single UAV in order to request some desired information updates about some target area then we need point-to-point type of communication. In point-to-many scenario, one node in the network needs to communicate with multiple others nodes. In MPI-CDL network operational scenario, when an UAV want to send message to multiple ground stations (field force) to guide them toward some target area then we need point-to-multi type of communication. In multi-to-point scenario, many nodes in the network needs to communicate with a single others nodes. In MPI-CDL network operational scenario, when many UAVs hovering above some target area want to send message to single ground station (field force) to guide them toward some target area then we need multi-to-point type of communication. In relay scenario, a node in the network needs to communicate with some other node which is not in its direct communication range. In MPI-CDL network operational scenario, as nodes UAVs and ground stations are moving so it's possible that not all nodes will be in the range of each other. In such cases, an intermediate node will relay the data thus acting as router between the source and destination nodes.

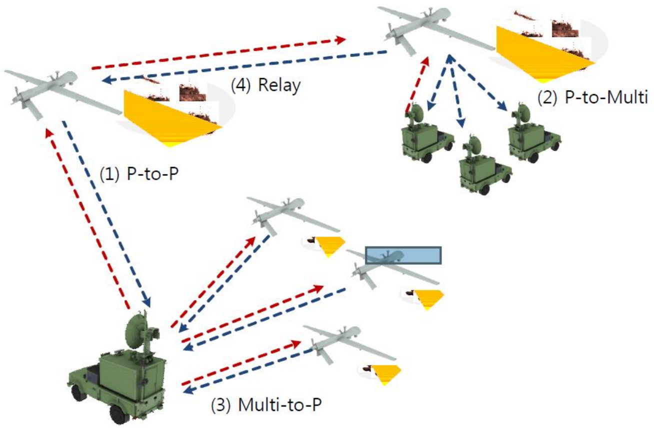

Figure 2. MPI-CDL Operational Scenarios.

SIMULATION ENVIRONMENT

In this section, we present of our preliminary simulation results. These simulations were conducted in OMNET++ simulator. Objective Modular Network Testbed in C++ (OMNeT++) a well-designed discrete event simulation environment [15]. The principle author is this simulator is Andras Varga from Technical University of Budapest (Hungary), and there are some occasional contributors. This is NOT just computer networks simulator, rather it has ability to simulate any kind of network e.g. queuing networks, digital logic networks etc.

OMNET++ has many supporting models for simulation of a particular kind of network scenarios. Among such model is INET. INET stands for Internet networking. This is a simulation package for OMNeT++ containing implementation models of protocols for many wired/wireless and mobile networks [16]. INET contains models for the Internet stack (TCP, UDP, IPv4, IPv6, OSPF, BGP, etc.), wired and wireless link layer protocols (Ethernet, PPP, IEEE 802.11, etc), support for mobility, MANET protocols, several application models, and many other protocols and components. This helps us test and simulate these network protocols in OMNET++ (without INET, we would have to write our own protocols). This model needs to be installed separately.

The following table presents the configuration for various parameters used in simulation.

Table 1. Simulation Parameters

Parameter	Value
No. of Nodes (UAVs)	2
No. of ground Nodes	4
Application Layer	MPI-CDL Application
Packet Size	1250 Bytes
Packet sending rate[1]	2500 and 12500 packets /sec
Transport Layer	UDP Protocol
Routing Layer	Fixed routing IP Protocol
MAC Layer	Ideal MAC
Carrier Frequency	15GHz
Bit Rate	64Mbps, 274Mbps
Max Communication Range	300 Km
Area Size	500 x 500 Km
Mobility Type	No Mobility
Node Speed	0 Km/hr
Simulation Time	25 sec

This work is mainly focused on adding MPI-CDL protocol and conduct performance analysis. For this purpose, first we have added MPI-CDL based application protocol at top layer

[1] *For data rate sending interval is normally distributed with mean 0.4ms and stddev 0.1μs*
For 274Mbps data rate sending interval is normally distributed with mean 0.08ms and stddev 0.1μs

to send and receive various control and command messages in the network as shown in Figure 3. In MPI-CDL application layer protocol, we try to capture basic functionality of UAV systems to send control and command messages.

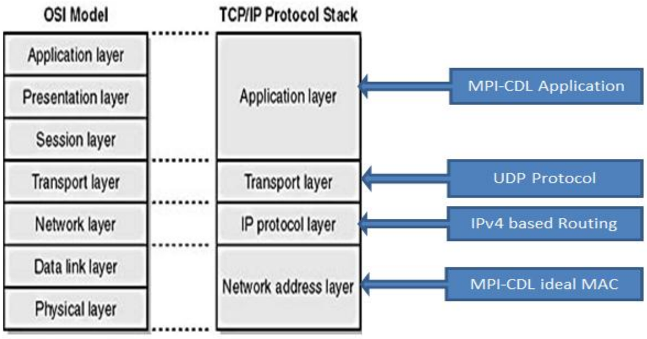

Figure 3. MPI-CDL Protocol Stack

We have performed simulation for two scenarios of MPI-CDL networks operation as shown in Figure 4. Thus, we have four scenarios as given below. One-to-One Scenario is one-to-one communication from node UAVA to FV1 with link data rate 274Mbps. One-to-Many Scenario is one-to-many communication from node UAVA to FV1, FV2 and FV3 with link data rate 274Mbps.

FV0, FV1, FV2 and FV3 are ground nodes and UAVA and UAVB are the two intermediate airborne network nodes to forward the data from source to destination. Communication ranges of nodes are shown in blue circle.

In the following sub-section, we describe results of each scenario in detail.

SIMULATION RESULTS AND PERFORMANCE EVALUATION

One-to-One Scenario (with data rate of 274Mbps)

Figure 4 shows the typical output screen of our simulation for One-to-One communication in OMNET++. This simulation was performed with channel data rate of 274Mbps. There are 02 UAVs and 04 ground nodes. In this scenario, we try to simulate relay mode operation where UAV-A wants to send data to FV3 and both are not in direct communication range of one another. Intermediate node UAV-B will forward the packets. The blue circle indicates the transmission range of each node.

We have executed the simulation for 25 sec and Figure 5 (a) shows the throughput results duration this time duration. The source node (UAV-A) was generating the data packets with sending interval is normally distributed with mean 0.08ms and stddev 0.1µs i.e. approx. 12500packets /sec where each packet size was 1250 Bytes. In other words, data was sent at 12500*1250*8= 125Mbps and the throughput graph shows that we are able to achieve around 127Mbps (on average).

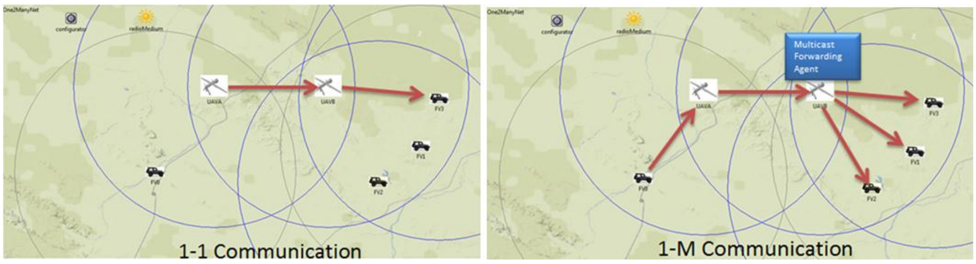

Figure 4. Selected scenarios for One-to-One and One-to-Many communication.

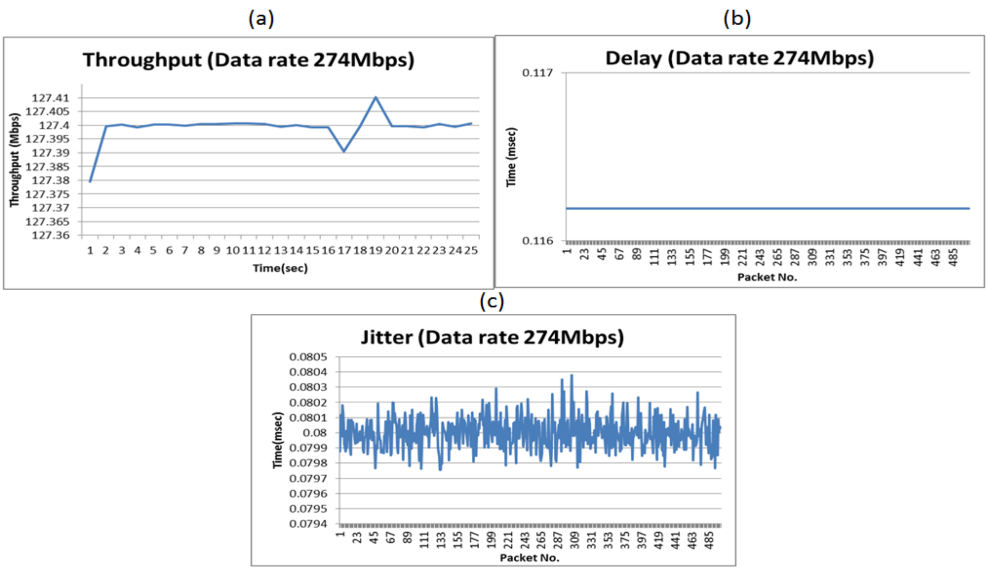

Figure 5. Simulation results for One-to-Many Scenario.

Delay graph of initial packets in One-to-One Scenario simulation is shown in Figure 5 (b) indicates that all packets arrived at destination, experiencing same delay of about 0.11msec which is very low. Further, we can see that there is no variation in delay graph.

Jitter values for initial packets in One-to-One Scenario simulation is shown in Figure 5 (c) indicates that for most the packets arrived at destination, experiencing inter packet delay i.e. jitter about 0.08msec which is very low.

One-to-Many Scenario (with data rate of 274Mbps)

Figure 4 shows the typical output screen of our simulation for One-to-Many communication in OMNET++. This simulation was performed with channel data rate of 274Mbps. There are 02 UAVs and 04 ground nodes. In this scenario, we try to simulate one to many mode of operation where FV0 wants to send data to FV1, FV2 and FV3. Source and destinations are not in direct communication range of one another. Intermediate nodes UAV-A and UAV-B will forward the packets. The blue circle indicates the transmission range of each node.

We have executed the simulation for 25 sec and Figure 6 (a) shows the throughput results duration this time duration. The source node FV0 was generating the data packets with sending interval is normally distributed with mean 0.08ms and stddev 0.1µs i.e. approx. 12500packets /sec where each packet size was 1250 Bytes. In other words, data was sent at 12500*1250*8= 125Mbps. Throughput graph shows that we are able to achieve around 127Mbps (on average).

Delay graph of initial packets in One-to-Many Scenario simulation is shown in Figure 6 (b) indicates that all packets arrived at destination, experiencing same delay of about 0.07msec which is very low. Further, we can see that there is no variation in delay graph.

Jitter values for initial packets in One-to-Many Scenario simulation is shown in Figure 6 (c) indicates that for most the packets arrived at destination, experiencing inter packet delay i.e. jitter about 0.08msec which is very low.

CONCLUSION AND FUTURE WORK

This concludes our simulation results for selected two scenarios i.e. one-to-one and one-to-many. Both scenarios were tested for 274Mbps data rates. For each data rate, we have tested different packet sending interval and observed that if we goes beyond a certain threshold than most of the packets get dropped at source MAC buffer. This may be due to some internal misconfiguration in OMNET++ and we will try to figure out its reason and solution. Furthermore, for these experiments, we have considered ideal MAC layer while ignoring collisions. If collision is allowed than, our results will significantly degrade. And if we use built-in 802.11 MAC layer protocols then we are unable to set data rate as desired. Furthermore, these simulations are performed with fixed routing i.e. no mobility. We will require some wireless routing protocol like OLSR if we want to introduce mobility in the network.

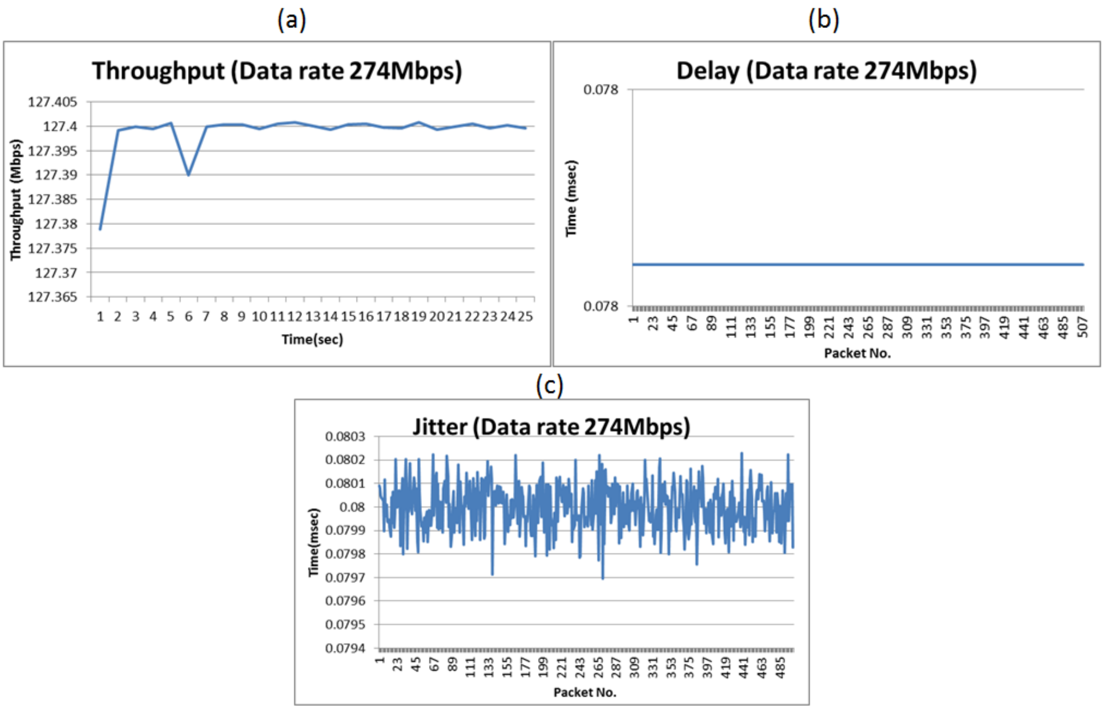

Figure 5. Simulation results for Scenario 4.

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