Software Defined Aircraft Ad-Hoc Network (SDAANET)

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Abstract: Airspace congestion, fuel costs, and environmental pollution are a few significant reasons due to which aviation has become difficult. These challenges are due to the unprecedented increase in air traffic. The advent of wireless ad-hoc networks has given rise to a particular category of an ad-hoc network, the Aircraft Ad-Hoc Network (AANET). Such a network is formed spontaneously in the air with aircraft as the networking nodes. With the development of smart air transportation systems, various new applications for transportation safety, efficiency as well as for providing onboard facilities to the passengers are required. Therefore, a flexible and innovative networking architecture is required for AANET. This paper proposes a Software Defined Aircraft Ad-Hoc Network (SDAANET). Combining the latest networking architecture Software Defined Network (SDN) with AANET leverages all the benefits provided by SDN.

***Index Terms* – Software Defined Network, Mobile Ad hoc Network, Vehicular Ad hoc Network, Aircraft Ad hoc Network.**

I. INTRODUCTION

In the present scenario, computer networks are being deployed in every field for imparting quick information, the transmission of critical data, Internet access, and remote dynamic interactions. Whereas, with the advent of wireless ad-hoc networks, it has become easy to deploy such networks within no time and without any infrastructure support. One such field where ad-hoc networks are being deployed is Aircraft Ad-Hoc Network (AANET). AANET may be categorized as a self-organizing ad-hoc network that is a subgroup of Vehicular Ad Hoc Networks (VANETs) where the participating nodes are aircrafts. In such a network, aircraft acts as a self-aware node that communicates with other aircrafts and also with the ground-based infrastructure. In such a network, the information is communicated within the same aircraft, aircraft-to-ground and aircraft-to-aircraft [1]−[4]. In the rest of the paper, Section II specifies the need for deployment of software defined AANET. Section III specifies the basic SDN architecture. Section IV describes the Software Defined Ad-Hoc Network (SDAANET) followed by a conclusion in Section V.

II. THE NEED FOR DEPLOYMENT OF SOFTWARE DEFINED AANET

AANET will solve most of the problems such as airspace congestion, environmental pollution, and fuel costs that arise due to the unpredictable increase in air traffic. AANET promises applications that can significantly benefit next-generation air transportation systems. With the development of air transportation systems, AANET will enable applications that may be categorized as (i) transportation safety (ii) transportation efficiency and (iii) user services delivered on the aircraft. The first two categories are the main objective for the development of AANET and include applications related to flight safety, schedule predictability, dynamic route planning as well as maintenance and operational efficiencies etc. The third category will combine benefits from both the newly developed and existing systems and will act as a market driving force. The services such as context conscious publicity will be provided using wireless long distance communication as convenience for passengers.
One such facility in this category is an eEnabled airplane that promises to revolutionize air travel. An eEnabled airplane participates as a self-conscious node in AANET and all round communication with the ground and other aircrafts. The eEnabled aircrafts will be equipped with advanced avionics and cost-effective wireless solutions to enhance control, maintenance, and operation.

Consequently, a large number of policies and applications are required to be built in AANET to facilitate air traffic and also provide the said services. It also requires communication between different AANET, whenever an aircraft moves from one network to another. Very high mobility of aircraft, high topology dynamics, limited bandwidth, connectivity losses, self-configuring, security issues are few challenges that exist in AANETs add this requires flexible network architectures for the safe and secure formation of such networks [5].

Even the demand to access the Internet on board is one of the uttermost requirements. In order to access Internet in regions such as deserts, marine, and in polar areas where it is not possible to built base stations or areas where it is not possible to develop a link between base-stations and the aircraft. In such situations, aircrafts have to use satellite links or to use significant multi-hop links within AANET to access base-stations. In these cases, aircraft needs to use satellite connections or use large multi-hop connections within AANET to reach the base stations. But, the satellite links suffer from large delays, limited bandwidth and high costs. AANET is therefore favored for internet access in these regions [6]. A new network architecture, Software-Defined Networking (SDN) is deployed to overcome (address) these challenges. SDN has emerged as a flexible way to control the network systematically by decoupling the two planes, the control, and the data plane. SDN has its bases focused on wired networks, specifically on data centers; its usage in other wireless scenarios has been gaining attention. SDN enables easy network innovations by network programmability [7].

III. SOFTWARE DEFINED NETWORK ARCHITECTURE

SDN is the network architecture in which the data and control planes are not located on the same networking feature. The packet transmission control in this is removed. It is performed through a controller, a logically centralized programmable machine, while the forwarding elements are used only as carry-package devices controlled by the controller.

Open APIs from controllers as well as data planes are accessible from the SDN architecture. OpenFlow (OF) is generally viewed as a generic SDN protocol to communicate between the controller and the forwarding hardware among many usable protocols. Open control to application communication APIs render designing network management systems simpler. Hence, SDN enables the network to be configured, giving numerous advantages. The network management is isolated from the forwarding hardware by SDN architecture and is a technically controlled control program that implements rules in forwarding hardware. The network traffic continues under such rules. Logically, an SDN can be represented in three levels.

Infrastructure Level

The layer comprises of transmission devices (router/switches) and covers the transmission hardware with all software interfaces and hardware combination.

Control Level

The logically centralized SDN controller installs network intelligence. The control level monitors and handles communication applications, i.e., Tier-1.

Application Level

Control layer and infrastructure levels are used by applications and services. The application level transcends the control level and facilitates the development of network application. All network management tasks are carried out by these applications [7, 8].

IV. SOFTWARE DEFINED NETWORK AIRCRAFT AD HOC NETWORK (SDAANET)

This section describes the architecture of SDAANET. Implementation of SDAANET enables flexibility, ease in implementation, and development of network-wide policies as well as applications. SDAANET also provides benefits of easy innovations, high scalability, simplified network management, robust fault tolerance, to name a few. Such networks are programmable and can be controlled according to the specifications and needs of the user [5]. One main reason for the easy implementation of SDAANET is because of aircrafts' connection to the ground station. During the start, flight, and its landing to the ground, most of the time, aircraft is connected to the ground base station [1]. By incorporating software defined controller software in the ground base station and also incorporating SDN components in the aircraft (the local agents), will enable AANET to leverage SDN benefits [9]−[12]. The proposed SDN based AANET system includes the following elements:

SDN Control Plane

SDN Control Program (controller) is the software-based logically centralized intelligence that is fully responsible for the management of aircrafts operations in the SDN based AANET system. Throughout SDN, the power over the exchange of packets in the network lives as software on the network servers at the base station. The rules are installed dynamically by the controller in the flow table and in compliance with the SDAANET the network communication is done. So, it is possible for the controller to programmatically control network traffic as well as alter, prioritize and shape it dynamically as per demands and requirements.

SDN Data Plane

These are the aircraft's data plane features, which can be controlled through the SDN controller. The features of an OpenFlow switch are included in it. Therefore, the SDN module combines the features of packet processing and an interface to receive the input from a different SDN control plane. The connectivity between SDN controller(s) based in servers in the ground base-station and SDN wireless node (the aircraft) specifies how the SDN controller controls these SDN wireless nodes. As specified earlier, whenever aviation of an aircraft starts till it lands on the ground, most of the time, it is connected to the ground base station. But, during its flight, there come situations when its connection to the ground base station is lost or interrupted. At this point, how the network behaves is a major issue in AANET. Depending on these situations as well as on the size of the network, three operational modes for Software Defined AANET are proposed: (i) large SDAANET managed by more than one SDN controller (ii) SDAANET managed by a single SDN controller (iii) SDAANET without connectivity between SDN controller and SDN based wireless nodes.

i. Large SDAANET Managed by More than One SDN Controllers

With the increase in the size of SDAANET it becomes impossible for a single controller to manage the entire network. Consequently, numbers of controllers are required to manage the SDAANET. As a result, large SDAANET may be further divided into multiple domains, and for each domain, there exists a single domain-specific controller. The controller makes decisions in its region. Moreover, in order to implement global policies, this controller may also interact with other controllers. Consequently, the domain controller controls all the actions of underlying aircraft in their specific domain. In specific, all the actions that the aircraft(s) perform are explicitly defined by the SDN domain controller. The SDN controller will push down all the flow rules on how to treat network traffic. These controllers may reside in various servers placed in a single ground base-station or may even reside on various servers placed in a different ground base-stations on earth as shown in Fig. 1.

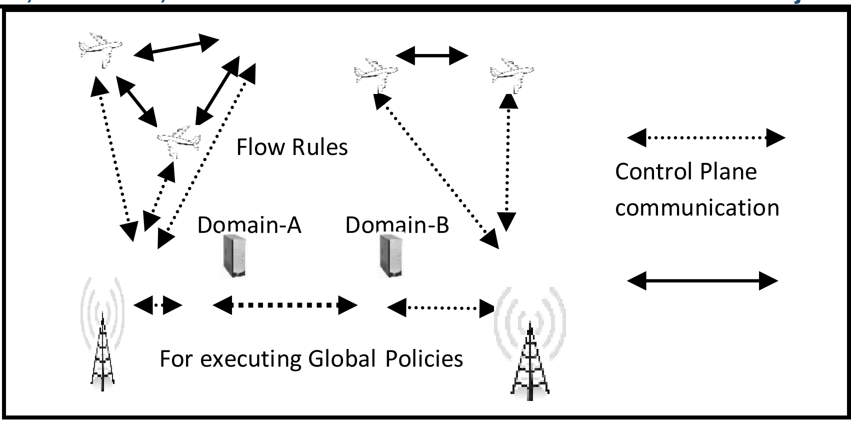

Fig. 1. Large SDAANET managed one SDN controller in each domain

ii. SDAANET managed by a single SDN controller

The mode controls all the operations of the underlying aircraft by a single SDN controller as shown in Fig. 2. In specific, all actions that the SDN data element residing in the aircraft(s) performs are explicitly defined by the SDN controller placed in servers at the ground base station. Particularly, the SDN controller on ground based station serves explicitly all behavior that the SDN data item exits in the aircraft(s). All the flow rules for handling traffic are pushed down by the SDN control unit.

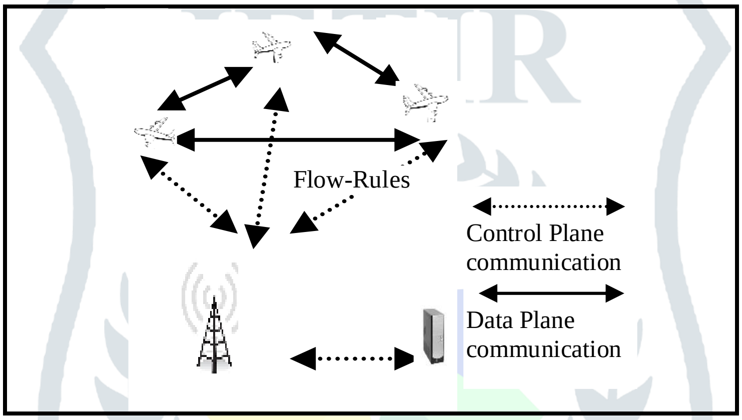

Fig 2.SDAANET managed by a single SDN controller.

iii. SDAANET without connectivity between SDN controller and aircraft

In deserts, in marine, or in a polar area it is not possible to build base stations or the areas it is not possible to develop a link between base-stations and the aircraft. SDAANET architecture can be deployed to work in these scenarios [6]. Therefore, during the flight of the aircraft, when the connectivity between the SDN controller on the ground- station and aircraft is lost, this mode becomes operational. One of the possibilities for establishing connectivity among aircrafts and ground station in SDAANET in this situation is to use multi-hop links among aircrafts to access base-station [6]. It is proposed that every aircraft in SDAANET have an SDN module known as SDN local agent as depicted in Fig. 3. This local agent is capable of performing control and data operations. In such situations, when the connection between aircraft and the base-station is lost, the local agent in every aircraft becomes operational. Packet processing is also performed by this local agent in every aircraft, and related information is transmitted to other aircrafts in a hop-by-hop manner. As the link between the aircraft and the base station is further established, the networking mode is transferred back to its previous one.

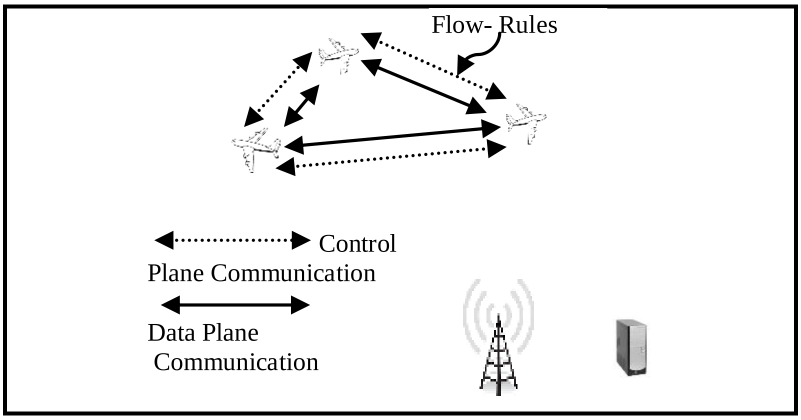

Fig 3.SDAANET mode without connectivity between SDN controller and aircrafts.

V. CONCLUSION

This paper proposed a Software Defined AANET. The logically unified device interface in SDN provides a holistic network view of the entire network for fast installation and operation of these networks. The sole purpose behind SDNs is to provide flexibility and easy innovations in networks. The SDNs' sole goal is to deliver simplicity and simple network technologies. Even the development, as well as the deployment of policy and applications, is easy because these may be easily added or deployed as controller applications in such networks. Consequently, SDAANET will provide features of increased adaptability, scalability, bandwidth as per need or requirement, ease in development of management, and security applications. Therefore, a SDAANET apart from providing flexibility and ease in innovations will allow easy management of such networks.

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