Flying Ad-hoc Networks: Review

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Abstract :

With the advancement of technology the role of UAV (Unmanned Aerial Vehicles) is growing rapidly. In the modern era very popular and advanced technologies are present which are used for communication purpose. With the advancement of technologies many challenging tasks are also associated like development and maintenance cost, integration etc. This paper reports the use of FANET in various areas and provides a path to known about the various challenging tasks in FANET. As literature indicated that the UAVs are attractive technology for many civilian and military applications. Due to the high and frequent mobility of the nodes, maintaining a communication link between the UAVs is a challenging task. Thus this paper lights on the main tasks of FANET and their use in the modern era.

I. INTRODUCTION

An Unmanned Aerial System (UAS) comprises of small UAVs which are very small in size, flexible and fast to deploy. In single-UAV applications, star topology network is present where UAV is in the centre. A ground node can indirectly communicate with others over the UAV. However, single UAV systems have some challenging issues in peerto-peer communication such as reducing interference, increasing transmission range and sending more data. A solution to these problems is the use of high gain directional antennas instead of Omni-directional antennas. In a single UAV system, if the UAV or a sensor/hardware fails, the UAV should return to the base. However, in multi-UAV systems, other UAVs can share tasks among themselves and this increases the fault tolerance of the system. In a heterogeneous UAV team, it is possible to use the capabilities of other UAVs. FANET is a subset of VANET. VANET routing protocols are not feasible or does not provide sufficient throughput for networks with highly mobile nodes. Usually, the topology of FANET change much frequently than MANET or vehicle ad hoc network (VANET). The most important network technology available nowadays for establishing FANETs is the IEEE 802.11a. Mesh ad hoc networks use 802.11s extension. In FANETs, two types of communication takes place: UAV-to-UAV communication and UAV-to-Infrastructure communication. In UAV-to-UAV communication, two UAVs can either directly communicates with each other i. e Single Hop Communication takes place or a Multi-Hop Communication path can be constructed over the other UAVs. In Case of UAV-to-

Infrastructure Communication, UAVs communicate with a fixed infrastructure such as a satellite or a ground station.

FANET can be viewed as a special form of MANET and VANET. However, there are also certain differences between FANET and the existing ad hoc networks:

a. Mobility degree of FANET nodes is much higher than the mobility degree of MANET or VANET nodes. While typical MANET and VANET nodes are walking men and cars respectively, FANET nodes fly in the sky.

b. Depending on the high mobility of FANET nodes, the topology changes more frequently than the network topology of a typical MANET or even VANET.

c. The existing ad hoc networks aim to establish peer-topeer connections. FANET also needs peer-to-peer connections for coordination and collaboration of UAVs. Besides, most of the time, it also collects data from the environment and relays to the command control center, as in wireless sensor networks. Consequently, FANET must support peer-to-peer communication and converge cast traffic at the same time.

d. Typical distances between FANET nodes are much longer than in the MANETs and VANETs. In order to establish communication links between UAVs, the communication range must also be longer than in the MANETs and VANETs. This phenomenon accordingly affects the radio links, hardware circuits and physical layer behavior.

e. Multi-UAV systems may include different types of sensors, and each sensor may require different data delivery strategies.

II. FANET DESIGN CHARACTERISTICS

Before discussing the characteristics of FANETs, we provide a formal definition of FANET and a brief discussion about the definition to understand FANET clearly. FANET can be defined as a new form of MANET in which the nodes are UAVs. According to this definition, single-UAV systems cannot form a FANET, which is valid only for multi-UAV systems. On the other hand, not all multi-UAV systems form a FANET. The UAV communication must be realized by the help of an ad hoc network between UAVs. Therefore, if the communication between UAVs fully relies on UAV-toinfrastructure links, it cannot be classified as a FANET. In the literature, FANET related researches are studied under different names. For example, aerial robot team is a collaborative and autonomous multi-UAV system, and generally, its network architecture is ad hoc. In this sense, ad hoc based aerial robot teams can also be viewed as a FANET design. However, aerial robot team studies mostly concentrate on the collaborative coordination of multi-UAV systems, not on the network structures, algorithms or protocols. Another FANET related topic is aerial sensor network. Aerial sensor network is a very specialized mobile sensor and actor network so that the nodes are UAVs. It moves around the environment, senses with the sensors on the UAVs and relays the collected data to the ground base. In addition, it can act with its actors on the UAVs to realize its mission. It is a perception issue to name the problem as flying ad hoc network or aerial sensor network. The basic design challenges of a traditional sensor network are energy consumption and node density and none of them is related with multi-UAV systems. Generally, UAVs have enough energy to support its communication hardware, and node density of a multi-UAV system is very low when it is compared to traditional sensor networks. Under the light of these discussions, it is better to classify the multi-UAV communication system based on UAV-to-UAV links as a specialized ad hoc network, instead of a specialized sensor network. UAV ad hoc network is another topic, which is closely related to FANETs. In fact, there is no significant difference between the existing UAV ad hoc network esearches and the above FANET definition. However, FANET term immediately reminds that it is a specialized form of MANET and VANET. Therefore, we prefer calling it as Flying Ad-Hoc Network, FANET.

III. AD HOC NETWORKING WITH FLYING NODES

FANETs are basically subclass of VANETs. These are located in the sub layer of an Aerial Network Layer. The Network Layer itself is responsible for the Data Transfer from the sender end to the receiver end and thus then selects an appropriate path for the data transmission to take place.

Figure 1 Multiple UAVs[24]

Using multi-UAVs in an ad-hoc network manner brings some advantages:

a. Cost: The maintenance cost of UAVs is small. UAVs are much lower than the cost of a large UAV.

b. Survivability: If the UAV fails in a mission which is operated by one UAV, the mission cannot proceed. However, if a UAV goes off in a multi-UAV system, the operation can survive with the other UAVs.

c. Scalability: Multi-UAV systems can extend the scalability of the operations easily.

d. Speed-up: It is shown that the missions can be completed faster with a higher number of UAVs. Small radar cross-section: Instead of one large radar crosssection, multi-UAV systems produce very small radar cross-sections, which is crucial for military applications.

e. Detectability: Mini-UAVs have low radar crosssections, low infrared signatures, and low acoustic signatures due to their sizes and composite structures.

Therefore, they may not be easily detectable by radars.

IV. FANET NETWORKING MODELS

FANET is a subclass of VANET and MANET. There are various routing algorithms for VANET and MANET but those are not applicable for FANET. The topology for FANETs, change much more frequently in comparison with VANET and MANET. For FANET, the various routing protocols have been implemented.

The various routing Protocols have been implemented for FANET as well. These protocols are categorized in four main classes:

A. Static Protocols: These are the protocols in which there is no need to refresh the tables. Tables cannot be updated during the operation. Static Protocols include various protocols:

   i. Load Carry and Delivery Routing (LCAD)

   ii. Multi-Level Hierarchical Routing

   iii. Data Centric Routing

B. Proactive Protocols: Every node maintains one or more tables representing the entire topology. It is a Table Drive approach. Proactive Protocols include the following protocols:

   i. Optimized link State Routing (OLSR)

   ii. Destination Sequenced Distance Vector (DSDV)

C. Reactive protocols: These are also known as the OnDemand protocols. These discover their path to deliver the messages and the data. The Reactive Protocols include the following:

   i. Dynamic Source Routing (DSR)

   ii. Ad Hoc On Demand Distance Vector (AODV)

D. Hybrid Protocols: These are the combination of both proactive and reactive protocols. The various hybrid protocols include the following protocols:

i. Zone Routing Protocol (ZRP)

ii. Temporarily Ordered Routing Algorithm (TORA)

The table below is representing the comparision of three networking models viz. MANET, VANET and FANET over different parameters.

Table 1 comparision (MANET, VANET, FANET)

Parameter	MANET	VANET	FANET
Node mobility	Low	High	Very high
Mobility model	Random	Regular	Regular for predetermined paths, but special mobility models for autonomous multi-UAV systems
Node density	Low	High	Very low
Topology change	Slow	Fast	Fast
Radio propagation model	Close to ground	Close to ground	High above the ground
LoS	LoS is not	LoS is not	LoS is available for most of the
	available for all cases	available for all cases	cases
Power consumption and network lifetime	Energy efficient protocols	Not needed	Energy efficiency for mini UAVs, but not needed for small UAVs
Computational power	Limited	High	High
Localization	GPS	GPS, AGPS, DGPS	GPS, AGPS, DGPS, IMU

V. APPLICATION SCENARIOS

In this section, different FANET application scenarios are discussed.

a. Extending the scalability of multi-UAV operations If a multi-UAV communication network is established fully based on an infrastructure, such as a satellite or a ground base, the operation area is limited to the communication coverage of the infrastructure. If a UAV cannot communicate with the infrastructure, it cannot operate. On the other hand, FANET is based on the UAV-to-UAV data links instead of UAV-to-infrastructure data links, and it can extend the coverage of the operation. Even if a FANET node cannot establish a communication link with the infrastructure, it can still operate by communicating through the other UAVs.

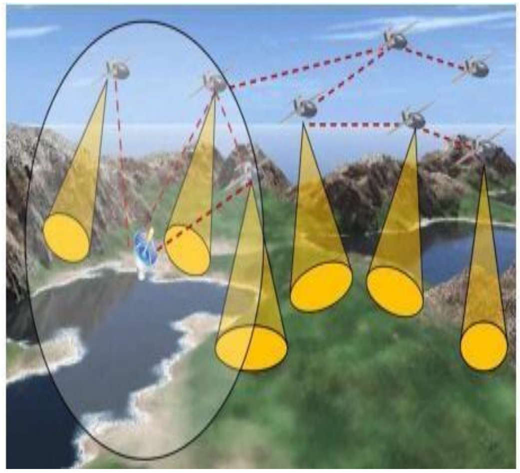

Figure 2 A FANET scenario to extend the scalability of multi- UAV systems[24]

b. Reliable multi-UAV communication

In most of the cases, multi-UAV systems operate in a highly dynamic environment. The conditions at the beginning of a mission may change during the operation. If there is no opportunity to establish an ad hoc network, all UAVs must be connected to an infrastructure, as illustrated in figure 3 (a). However, during the operation, because of the weather condition changes, some of the UAVs may be disconnected.

If the multi-UAV system can support FANET architecture, it can maintain the connectivity through the other UAVs, as it is shown in Fig. 3 (b). This connectivity feature enhances the reliability of the multi-UAV systems.

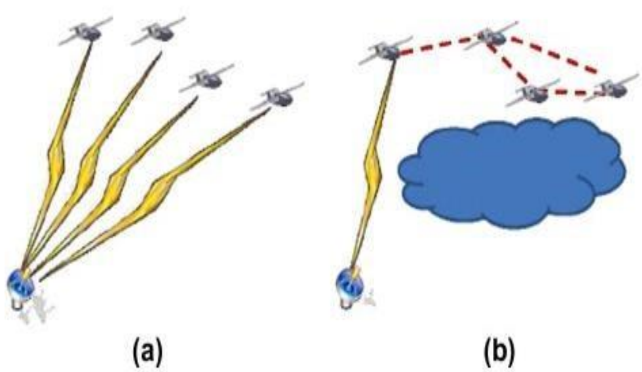

Figure 3 FANET application scenario for reliable multi-UAV communication network[24]

C. FANET to decrease payload and cost The payload capacity problem is not valid only for small UAVs. Even High Altitude Low Endurance (HALE) UAVs must consider payload weights. The lighter payload means the higher altitude and the longer endurance [16]. If the communication architecture of a multi-UAV system is fully based on UAV-to-infrastructure communication links, each UAV must carry relatively heavier communication hardware. However, if it uses FANET, only a subset of UAVs use UAV-to-infrastructure communication link, and the other UAVs can operate with FANET, which needs lighter communication hardware in many cases. In this way, FANET can extend the endurance of the multi-UAV system.

D. UAV swarms

Small UAVs are very light and have limited payload capacity. In spite of their restricted capabilities, the swarm behavior of multiple small UAVs can accomplish complex missions [21]. Swarm behavior of UAVs requires coordinated functions, and UAVs must communicate with each other to achieve the coordination. However, because of the limited payloads of small UAVs, it may not be possible to carry heavy UAV-to-infrastructure communication hardware. FANET, which needs relatively lighter and cheaper hardware, can be used to establish a network between small UAVs. By the help of the FANET architectures, swarm UAVs can prevent themselves from collisions, and the coordination between UAVs can be realized to complete the mission successfully.

VI. PROGRESS TILL NOW

C. Dearlove, T. Clausen, and P. Jacquet, “The Optimized Link State Routing Protocol version 2," IETF Draft RFC draft-ietf-MANET-OLSRV2-10, 2009.

The Optimized Link State Routing (OLSR) protocol for mobile ad hoc networks. The protocol is an optimization of the classical link state algorithm tailored to the requirements of a mobile wireless LAN. The key concept used in the protocol is that of multipoint relays (MPRs). MPRs are selected nodes which forward broadcast messages during the flooding process. This technique substantially reduces the message overhead as compared to a classical flooding mechanism, where every node retransmits each message when it receives the first copy of the message. In OLSR, link state information is generated only by nodes elected as MPRs. An MPR node may choose to report only links between itself and its MPR selectors. Hence, as contrary to the classic link state algorithm, partial link state information is distributed in the network. This information is then used for route calculation.[2]

Joel George , Sujit P. B. , J. B. Sousa, Search Strategies for Multiple UAV Search and Destroy Missions, Journal of Intelligent and Robotic Systems, v.61 n.1-4, p.355-367, January 2011.

Multiple UAVs are deployed to carry out a search and destroy mission in a bounded region. The UAVs have limited sensor range and can carry limited resources which reduce with use. The UAVs perform a search task to detect targets. When a target is detected which requires different type and quantities of resources to completely destroy, then a team of UAVs called as a coalition is formed to attack the target. The coalition members have to modify their route to attack the target, in the process, the search task is affected, as search and destroy tasks are coupled. In this paper, they propose three different search strategies namely; random search strategy, lanes based search strategy and grid based search strategy and analyze their performance through Monte-Carlo simulations. The results show that the grid based search strategy performs the best but with high information overhead.[5]

I. Bekmezcia, O. K. Sahingoza, and S. Temel, “Flying Ad- Hoc Networks (FANETs): A survey,” Ad Hoc Networks, vol. 11, no. 3, pp. 1254–1270, May 2013. One of the most important design problems for multi-UAV (Unmanned Air Vehicle) systems is the communication which is crucial for cooperation and collaboration between the UAVs. If all UAVs are directly connected to an infrastructure, such as a ground base or a satellite, the communication between UAVs can be realized through the infrastructure. However, Flying Ad-Hoc Networks (FANETs) are surveyed which is an ad hoc network connecting the UAVs. The differences between FANETs, MANETs (Mobile Ad-hoc Networks) and VANETs (Vehicle Ad-Hoc Networks) are clarified first, and then the main FANET design challenges are introduced. Along with the existing FANET protocols, open research issues are also discussed.[8]

S. Rosati, K. Kruzelecki, L. Traynard, and B. Rimoldi, "Speed-aware routing for UAV- Ad-Hoc networks," in accepted at IEEE GLOBECOM 2013, 4th International IEEE Workshop on Wireless Networking & Control for Unmanned Autonomous Vehicles: Architectures, Protocols and Applications, 2013.

In this paper, they examined mobile ad-hoc networks (MANET) composed by unmanned aerial vehicles (UAVs). Due to the high-mobility of the nodes, these networks are very dynamic and the existing routing protocols partly fail to provide a reliable communication. They present PredictiveOLSR an extension to the Optimized Link-State Routing (OLSR) protocol: it enables efficient routing in very dynamic conditions. The key idea is to exploit GPS information to aid the routing protocol. Predictive-OLSR weights the expected transmission count (ETX) metric, taking into account the relative speed between the nodes. They provide numerical results obtained by a MAC-layer emulator that integrates a flight simulator to reproduce realistic flight conditions. These numerical results show that Predictive-OLSR significantly outperforms OLSR and BABEL, providing a reliable

communication even in very dynamic conditions. [7]

Ozgur Koray Sahingoz.: “Mobile networking with UAVs: Opportunities and Challenges” In: International Conference on Unmanned Aircraft Systems (ICUAS-2013), pp. 933– 941, 2013.

In recent years, the capabilities and roles of Unmanned Aerial Vehicles (UAVs) have rapidly evolved, and their usage in military and civilian areas is extremely popular as a result of the advances in technology of robotic systems such as processors, sensors, communications, and networking technologies. The focus is changing from use of one large UAV to use of multiple UAVs. Setting up an ad-hoc network between flying UAVs is a challenging issue, and requirements can differ from traditional networks, Mobile Ad-hoc Networks (MANETs) and Vehicular Ad-hoc Networks (VANETs) in terms of node mobility, connectivity, message routing, service quality, application areas, etc. This paper identifies the challenges with using UAVs as relay nodes in an ad-hoc manner, introduces network models of UAVs, and depicts open research issues with analyzing opportunities and future work.[9]

Gregoire Heitz, Dario Floreano and Bixio Rimoldi " Dynamic Routing for Flying Ad-Hoc Networks (FANETs): A survey," Ad Hoc Networks, vol. 11, no. 3, pp. 1254–1270, 17 June 2014.

Flying ad hoc networks (FANETs) composed of small unmanned aerial vehicles (UAVs) are flexible, inexpensive and fast to deploy. This makes them a very attractive technology for many civilian and military applications. The main challenge is due to the high-mobility of the nodes. The topology of these networks is more dynamic than that of mobile ad hoc networks (MANETs) and of vehicle ad hoc networks (VANETs). As a consequence, the existing routing protocols designed for MANETs partly fail to track network topology changes. Extension of OLSR is used called POLSR. P-OLSR is currently the only FANET-specific routing technique which has an available Linux implementation. The experimental results show P-OLSR significantly outperforms OLSR in rerouting in the presence of frequent network topology changes.[10]

VII. CONCLUSION

In this paper we studied the various issues of FANET in the modern era and we also discussed the difference between FANET, MANET and VANET. Thus our literature indicates that efforts can be done to enhance the performance of protocols to increase the efficiency of FANET as well. Various protocols are used which can be enhanced can be can be compared with the various metrics for the performance evaluation.

VIII. REFERENCES

[1] T. Clausen and P. Jacquet, "Optimized Link State Routing Protocol (OLSR)," RFC 3626, Oct. 2003.

[2] C. Dearlove, T. Clausen, and P. Jacquet, "The Optimized Link State Routing Protocol" version 2," IETF Draft RFC draft-ietf-manet-olsrv2-10, 2009.

[3] Alshbatat and L. Dong, Cross layer design for mobile Ad-Hoc Unmanned Aerial Vehicle communication networks," in Networking, Sensing and Control (ICNSC), 2010 International Conference on, April 2010.

[4] Z. Sun, P. Wang, M. C. Vuran, M. Al-Rodhaan, A. AlDhelaan, and I. F. Akyildiz, BorderSense: Border patrol through advanced wireless sensor networks."Ad Hoc Networks", vol. 9, no. 3, pp. 2011.

[5] Joel George , Sujit P. B. , J. B. Sousa, Search Strategies for Multiple UAV Search and Destroy Missions, Journal of Intelligent and Robotic Systems, v.61 n.1-4, p.355367, January 2011.

[6] Y. Guo, X. sLi, H. Youse'zadeh, and H. Jafarkhani, UAV-aided cross-layer routing for MANETs," in Wireless Communications and Networking Conference (WCNC), 2012 IEEE, April 2012.

[7] S. Rosati, K. Kruzelecki, L. Traynard, and B. Rimoldi, "Speed-aware routing for UAV- Ad-Hoc networks," in accepted at IEEE GLOBECOM 2013, 4th International IEEE Workshop on Wireless Networking & Control for Unmanned Autonomous Vehicles: Architectures, Protocols and Applications, 2013.

[8] Bekmezcia, O.K. Sahingoza, and S. Temel, "Flying AdHoc Networks (FANETs): A survey,"Ad Hoc Networks, vol. 11, no. 3, pp. 1254–1270, May 2013.

[9] Ozgur Koray Sahingoz.: "Mobile networking with UAVs: Opportunities and Challenges" In: International Conference on Unmanned Aircraft Systems (ICUAS2013), pp. 933–941, 2013.

[10] Gregoire Heitz, Dario Floreano and Bixio Rimoldi " Dynamic Routing for Flying Ad-Hoc Networks (FANETs): A survey," Ad Hoc Networks, vol. 11, no. 3, pp. 1254–1270, 17 June 2014.

[11] C. Dearlove, T. Clausen, and P. Jacquet, "The Optimized Link State Routing Protocol version 2," IETF Draft RFC draft-ietf-manet-olsrv2-10, 2009. [Online]. Available: http: //tools.ietf.org/id/draft-ietf-manetolsrv2-19.txt

[12] W. Frew and T. X. Brown, "Networking Issues for Small Unmanned Aircraft Systems," Journal of Intelligent and Robotic Systems, vol. 54, no. 1-3, p. 21,

2008. [Online]. Available : http://dx.doi.org/10.1007/s10846-008-9253-2

[13] Y. Guo, X. Li, H. Yousefi"zadeh, and H. Jafarkhani, "UAV-aided cross-layer routing for MANETs," in Wireless Communications and Networking Conference (WCNC), 2012 IEEE, April 2012, pp. 2928–2933.

[14] Alshbatat and L. Dong, “Cross layer design for mobile Ad- Hoc Unmanned Aerial Vehicle communication networks,” in Networking, Sensing and Control (ICNSC), 2010 International Conference on, April 2010, pp. 331–336.

[15] M. Benzaid, P. Minet, and K. Al Agha, “Integrating fast mobility in the OLSR routing protocol,” in Mobile and Wireless Communications Network, 2002. 4th International Workshop on, 2002, pp. 217–221.

[16] M. Benzaid, P. Minet, and K. Al-Agha, “Analysis and simulation of fast-OLSR,” in Vehicular Technology Conference, 2003. VTC 2003-Spring. The 57th IEEE Semiannual, vol. 3, April 2003, pp. 1788–1792 vol.3.

[17] Aloul, F.A., Kandasamy, N. “Sensor deployment for failure diagnosis in networked aerial robots: a satisfiability-based approach, theory and applications of satisfiability testing” SAT 2007. Lect. Notes Comput. Sci. 4501, 369–376 (2007)

[18] Shirani, R., St-Hilaire, M., Kunz, T., Zhou, Y., Li, J., Lamont, L.”Combined reactive-geographic routing for unmanned aeronautical ad-hoc networks”

[19] 8thInternational Wireless Communications and Mobile Computing Conference (IWCMC-2012), pp. 820–826 (2012)

[20] Li, Y., St-Hilaire, M., Kunz, T.”Enhancements to reduce the overhead of the reactive-greedy-reactive routing protocol for unmanned aeronautical ad-hoc networks.” In: 8th International Conference onWireless Communications, Networking and Mobile Computing (WiCOM), pp. 1–4 (2012)

[21] Cai, Y., Yu, F.R., Li, J., Zhou, Y., Lamont, L.”Medium access control for Unmanned Aerial Vehicle (UAV) adhoc networks with full-duplex radios and multipacket reception capability” IEEE Trans. Veh. Technol. 62(1), 390–394 (2013)

[22] Reynaud, L., Rasheed, T.”Deployable aerial communication networks: challenges for futuristic applications.” In Proceedings of the 9th ACM Symposium on Performance Evaluation of Wireless AdHoc, Sensor, and Ubiquitous Networks (PE-WASUN „12), pp. 9–16 (2012)

[23] Bök, P.-B., Tuchelmann, Y.”Context-aware QoS control for wireless mesh networks of UAVs.” International Conference Computer Communications and Networks (ICCCN), pp. 1–6 (2011)

[24] Li, Y., St-Hilaire, M., Kunz, T. “Improving routing in networks of UAVs via scoped flooding and mobility prediction” IFIP Wireless Days (WD), pp. 1–6 (2012)

[25] Bekmezci, I. Ermis, M. ; Kaplan, S., “Connected multi UAV task planning for Flying Ad Hoc Networks” IEEE International Black Sea Conference on Communications and Networking (BlackSeaCom), 28-32, 2014.