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An Energy Aware Cluster Based Routing Framework for IoMT Based Flying Adhoc Networks

M. M. M. Bagram[1], N. Ahmad[2], H. Ali[3]

[1]*Department of Business Administration, Allama Iqbal Open University, Islamabad, Pakistan*
[2]*Faculty of Engineering & Computing, National University of Modern Languages Islamabad, Pakistan,*
[3]*National University of Modern Languages, Islamabad, Pakistan*

[1]majidbagram@aiou.edu.pk

Abstract- The integration of Flying Ad hoc Networks (FANETs) with Internet of Medical Things (IoMT) has introduced new opportunities and challenges in emergency healthcare delivery, especially in remote and hard-to-reach areas. This research proposes an Energy Aware Cluster Based Routing Protocol for FANETs (EA-CBRP-FAN) to enhance energy efficiency, scalability, and reliability in real-time medical data transmission. The proposed framework segments the network into cells and clusters, where sensor nodes (Cluster Members) collect vital health parameters and transmit them to Cluster Heads, which forward the data to base stations. These base stations interface with a healthcare application via cellular infrastructure, facilitating remote access to patient data for medical staff and emergency services. The network architecture also incorporates Internet of Drones (IoD) to support rapid medical response in areas inaccessible by ground transport. Performance evaluation using a Neural Network classifier shows the proposed protocol achieving approximately 42% accuracy across key metrics including precision, recall, and F1-score. The results affirm the protocol's potential to support energy-efficient, prioritized, and resilient data routing in UAV-assisted IoMT environments.

I. INTRODUCTION

Health care can now be delivered on-demand via the Internet due to the proliferation of wireless body area networks (WBANs) and the Internet of Medical Things (IoMT) in modern smart cities [1]. Low-power biosensors and an on-body aggregation node called a hub are used to equip coexisting patients in IoMT-based WBANs. The hub receives periodic readings from the bio-sensors, including Respiration Rates (RRs), Systolic Blood Pressure (SBPs), Temperature (TMPs), Electrocardiograms (ECGs), and Oxygen Saturation levels (SpO2). A monitoring centre receives the data from the hub via Access Points (APs) for further processing. With WBANs, patients' vital signs can be monitored in real-time without disrupting their daily routines [2]. Patients in crisis have sensitive vital signs, so this information needs to be communicated to the monitoring centre as quickly as feasible. Biosensors like the electrocardiogram (ECG) have priority over others like the body temperature when trying to access the channel. Patient data transmission has a higher priority than that of non-medical patients and biosensors. It is important to prioritise communication channels for patients in a medical emergency. An appropriate emergency index mechanism must be developed for all of the factors mentioned above to impact the schedule significantly.

1.1 Internet of Medical Things (IOMT)

Resource allocation, co-channel interference reduction, and traffic management are important issues for IoMT-based WBANs. As a result, Walsh Hadamard (WH) codes can maximise energy efficiency and minimise interference between transmissions. The WH matrix orthogonal code can be used to relay data from many sensors simultaneously.

1.1.1 IoMT Challenges

APs' limited ability to send data packets over IoMT-based WBAN hubs is another significant challenge. NOMA, such as Time Division Multiple Access (TDMA), is an emerging solution to this problem, as it provides higher spectral efficiency than OMA (TDMA). The NOMA approach allows some degree of interference between concurrent transmissions compared to the OMA strategy, which only allows simultaneous scheduling of broadcasts that do not interfere with each other (though at the expense of spectrum efficiency loss). For the Successive Interference Cancelation (SIC) mechanism to recognise the received signal correctly, a predefined SNR threshold must be met. Thus, the spectral efficiency of the NOMA scheme is improved by scheduling more concurrent transmissions in a single time slot compared to OMA [3]. Each transmitter's signal is separated when the receiver receives all simultaneous transmissions. Every time the SIC mechanism separates the strongest signal, it assumes that other signals are interfering with it. If a network fails to deal with the challenges above, it will perform poorly. IoMT-based WBANs rely on edge servers and Software-Defined Controller (SD) controllers to ensure that the hub and APs communicate with each other and the monitoring centre effectively [4-5]. In a still-emerging network design, edge servers do some processing activities. Similarly, SD data and control planes are separated, and all administration procedures are assigned to the SD controller.

1.1.2 IoMT Security Issue

The usage of IoMT devices greatly improves the patient's treatment. RFID sensors, pacemakers, insulin pumps, defibrillators, and cardiac defibrillators, to name a few, are all routinely used medical equipment. A wide range of potential problems have been identified with these gadgets. According to a detailed assessment of IoMT security concerns, RFID Tags have security issues such as wireless assaults and electromagnetic interference. Attacks on IMDs, such as the denial of power, radio, and device cloning, as well as issues with authentication, firmware updates, traffic monitoring, and message tampering, are fairly common. Many issues with third-party intrusion and hijacking attacks affect wearable external devices. The work also examined IoMT's common security issues, which were discussed. An investigation of power denial attacks, security flaws in ambient assisted living (AAL), and this IoMT evaluation recommends software-defined networking protocols.

II. LITERATURE REVIEW

Advances in wireless technology have recently taken care of the needs for mobile, flexible, and far-reaching communication. In a WANET, communication between nodes can be accomplished without the use of a central hub. Small and flexible devices, such as unmanned UAV systems, can be linked together in FANETs, which can be controlled remotely without the need for a human operator. Because of their advantages, both the military and civilian sectors have begun to embrace FANET technology in recent years. FANET's smart vehicles (nodes) are drones equipped with high-resolution cameras, wireless devices, computers, sensors, digital maps, and GPS. Multiple unmanned aerial vehicles (UAVs) build an ad-hoc network as shown in Fig. 4.2.1 and communicate with one another to form an integrated system within FANET.

As with traditional telephone calls, all UAVs in the network can communicate with each other via U2U (UAV-to-UAV communication). UAVs can communicate over short or long distances, depending on the amount of data and information they need to transfer. U2I (UAV-to-infrastructure) communication is another term for this type of communication (U2I). Here, a single UAV or a fleet of them connect to a ground station (also known as a "base station") to exchange data and information about their missions. Health Monitoring Planning for Ships Through Flying more UAVs can be parallelised in FANET, which reduces the mission's completion time [6]. The concept and technology of FANETs saved many people's lives, proving their worth. Types of Wireless Ad-Hoc Networks include all those that serve a specific purpose and are used in some way. FANET defines it as a communication network of multiple unmanned aerial vehicles. It's also an advanced form of the previously existing MANET (mobile ad-hoc network) and VANET (vehicular ad-hoc network). FANET and previous ad hoc networks share many common characteristics but differ significantly in important ways.

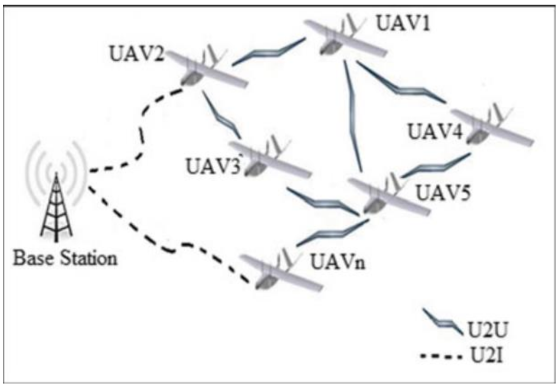

Figure 1: FANET Architecture

2.1 Flying Ad hoc Networks

As the name suggests, FANETs are small unmanned aerial vehicles (UAVs) linked together on an as-needed basis to form an autonomous wireless network. To name just a few potential uses for unmanned aerial vehicles (UAVs), they include disaster monitoring and relief efforts such as search and rescue and border surveillance, ad hoc network relay and wildfire management. FANET basics, applications, and challenges are explained in great detail in [6], and researchers are encouraged to look for new ways to solve the open problems in FANETs by examining various solutions and new analyses. Connected health sensors are attached to the human body and broadcast and receive health data such as heart rate and blood pressure over a wireless network. Wearable technology is widely used for various purposes, including remote medical diagnosis, athletic training, and military training. UAV-based health monitoring systems have also been developed by [7] to prevent human life disasters in remote areas, such as mountains, where communication is difficult. To save lives and keep ships safe from disaster, a study of the ship's health monitoring strategy employing FANET and WBAN has yet to be done.

2.2 Classification of Flying Ad hoc Network UAV

Drones, also known as unmanned aerial vehicles (UAVs), have found use in various industries, including wildfire monitoring, agriculture, telecommunications, and border surveillance [8]. It is possible to categorise UAVs based on the type of flight, such as remotely controlled autonomous, wing type, size, and ability to communicate with other UAVs. Rotary-wing UAVs (RW-UAVs) and Fixed-wing UAVs (FW-UAVs) are the two main types of wings. In contrast to FW-UAVs, Vertical takeoff and landing (VTOL) is possible with RW-UAVs and is more stable (can control roll, yaw and pitch, and throttle), and can hover over stationary points. It's important to distinguish between single UAV and multi-UAV systems when it comes to communication capabilities [9]. Most civil and military multi-UAV systems currently use a swarm or formation of small UAVs, a new trend. The term "flying ad hoc network" (FANET) refers to this approach, which has several advantages, including shorter completion times, lower costs, increased scalability, and higher reliability [10].

2.2.1 Common Characteristics of Flying Adhoc Networks

The followings are the Common Characteristics of Flying Adhoc Networks:

1. *Mobility Model:* FANETs' mobility models have generally followed a set pattern. Due to mission updates, autonomous multi-UAV systems do not have a predetermined flight plan. The flight plan must therefore be recalculated.
2. *Node Mobility:* Flying nodes (UAVs) have a much higher mobility degree than VANET and MANET nodes (such as cars) (like laptops). A wide range of communication protocol issues arises due to the UAV's speed, which ranges from 30 to 450 kilometres per hour (km/h).
3. *Radio Propagation Model*: Most of the time, the nodes of the MANET and VANET networks are within a few hundred metres of the ground, whereas those of the FANET network are hundreds of kilometres above it. As a result, a new, more efficient FANET radio propagation model is required.
4. *Network Topology Change:* Due to the mobility of the higher nodes in FANET, the network's topology changes frequently. As a result, there will be no way for UAVs to communicate with one another. Consequently, new routing methods must be devised to ensure uninterrupted communication between UAVs.
5. *Node Density:* The average number of nodes per square metre in a MANET is called the node density. FANET's UAVs can be dispersed over several kilometres. As a result, the number of nodes in the FANET is lower than that of the MANET and VANET, respectively.
6. *Localisation:* Most FANET applications necessitated extremely fast and precise localisation data. GPS and IMU are required to provide the precise location of each special UAV to the other UAVs at all times, even though GPS is sufficient for VANET uses MANET and AGPS and DGPS.
7. *Computational Power:* Due to their role as routers in FANET, UVA nodes are well-suited to supporting heavy computational demands. VANET also has a lot of computing power built into it. As a result of their small size and battery limitations, nodes in MANET have only a limited amount of computational power.
8. *Network Lifetime and Power Consumption:* Communication gear in FANET is not powered sensitive, as it is powered by the UAV's energy source, in contrast to MANET applications. Miniature UAVs, on the other hand, may have difficulty with this.

Based on a common property shared by all ad hoc networks, the data in Table 1 compares MANETs, VANETs, and FANETs. FANETs can solve the constraints of the preceding standard network in disaster situations and military settings. Putting moveable nodes in high-risk or disaster-prone areas is problematic because of MANET. FANETs can successfully tackle challenges like search, monitoring, and rescue operations with flying nodes like drones [11].

Table 1: Ad Hoc Networks Comparison

VANET	MANET	FANET
High node density	Low node density	Very low node density
Regular mobility model Required	Random mobility model required	Regular mobility model, however autonomous multi-UAVs may necessitate the use of alternative models.
Node mobility is High	Node mobility is very low	Node mobility is very High
GPS, AGPS, and DGPS are utilised to deliver precise location information in the real world.	Node movement is extremely restricted. The location information can be obtained via GPS.	UAVs with very high node mobility are tracked using GPS, AGPS, DGPS, and inertial measurement units (IMUs).
There is an average amount of computing power in each node (vehicle).	The nodes' computing power is restricted.	There is a lot of computational power in nodes (UAVs).
LoS is not necessary because all vehicles are on	LoS is not necessary because all nodes are near	The ground base node is a long way from the UAV nodes. As a result, in most circumstances,

the ground.	the ground.	the nodes have a clear line of sight (LoS).
It is not power sensitive	Energy efficient protocol required	Mini-UAVs are not power sensitive, but they face unique challenges because of their small size.
Topology changed is Fast	Topology changed is slow	Topology changed very frequently

2.3 Routing Protocols in Flying Adhoc Networks

Ad-Hoc networks have necessitated the development of routers that consider each node's topology and position in the cluster. It was only natural for researchers to examine how the protocols used in MANET and VANET, two other subclasses of mobile ad hoc networks, could be applied to unmanned aerial vehicle networks. FANET nodes' high speed, energy constraint, and fast connectivity changes preclude most of these protocols from being used directly. As a result, these protocols must be modified to meet FANET requirements. Additional protocols for Ad-Hoc networks have also been proposed in the literature. Figure 2 shows each subcategory.

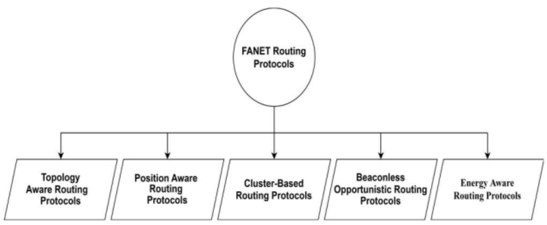

Figure 2: FANET (Flying Ad Hoc Network) Routing classification [12]

2.3.1 TARPS (Topology Aware Routing Protocols)

The network's topology changes dramatically due to the rapid mobility of FANET nodes. Networks can be disrupted by topological and structural changes that are dynamic and asymmetrical. It has led to many knowledge-based routing protocols being proposed as a solution. Adding new information, such as movement patterns, to the routing process is the goal. Based on MANET's standard capability, several topology-adjusting routing protocols are currently being developed. Among these are the introduction of GPS location characteristics and the direct deployment in FANET. A node can learn about its surroundings over time to better adapt to a more diverse environment.

In some cases, different routing protocols can be used in conjunction. It implements routing protocols that use topology-based routing protocols, such as the TCM (Topology Construction Method), Distributed Priority Tree-Based Routing Protocol and TARCS (Topology Change Awarding Based Routing Choice Scheme). SDN (Software-defined networks) have also been implemented into topology-aware routing for FANETs. According to [13], an SDN-based FANET coordination protocol that integrates efficient UAV communication and SDN-based topology management algorithms has been developed for FANET administration. By using relay-based communication between nodes that are autonomously doing separate or combined activities, the FANET topology hopes to accomplish this.

2.3.2 PARPS (Position Aware Routing Protocols)

A user's precise location determines the best route to take. Each node can use GPS to establish a geographical broadcast of this information to communicate its speed and location with its neighbours. RLS (Reactive Location Service) or GLS (Grid Location Service) can be used by the node to determine the location of the destination (HLS). FANETs, with their high rate of change, are well-suited to nodes making local judgments rather than looking at the overall network status. Due to node mobility being unpredictable, this solution eliminates the problem of network node disconnections. If someone is looking for a routing protocol, there are three types to choose from non-DTN, DTN, and heterogeneous. The robustness and reliability of some protocols, such as RARP, JamRout, and GCS (Ground Control System) Based Routing and AntHocNet, are based on position-based routing protocols.

2.3.3 CBRPS (Cluster-Based Routing Protocols)

An algorithm known as clustering can be used to break down a large network into a series of smaller groups, known as "subclusters". To deal with FANET's resource scarcity problem, clustering is a strategy for identifying nodes that share a common geographic neighbourhood. The role of the cluster head (CH) in each subcluster is to act as a coordinator. Hence, each CH is considered a temporary Base Station (BS) in the cluster in which it is placed. Group network nodes are formed using this strategy, and the clusters overlap. Hierarchical routing can be made easier with clustering because it records pathways between clusters rather than nodes. There is less routing overhead, more throughput, longer route lifetime and reduced UAV energy consumption.

2.3.4 BORPS (Beaconless Opportunistic Routing Protocol)

Instead of using direct connections between source and destination nodes, ad hoc networks use the mobility of their nodes to communicate with one another. Wireless sensor networks, MANETs, and other multi-hop wireless networks lack a way to fix broken network connections. A broken link can cause significant degradation in networking efficiency and even result in the network going down. Topological structures can change, and connections are not always guaranteed in practice. Because of this, the routing protocol must be studied to establish the most efficient data transmission channel to assure work completion speed. Because they use beaconless opportunity routing methods, these protocols help maintain network connectivity even when links are slow or unavailable. Beaconless Opportunistic Routing Protocol is used by several protocols, including Adaptive CABR (Context-Aware Beaconless Opportunistic Routing Protocol), XlinGO (Geographical-Aware Beaconless Opportunistic Routing Protocol), and CLQ (Cross-Layer Link Quality).

2.3.5 EARPS (Energy Aware Routing Protocols)

Aerial vehicles and wireless body area networks (WBANs) can be used to collect and transmit health data. As a result of the uneven energy consumption of flying items, missions will fail sooner, and the network's lifespan will be reduced. An ant-based routing system, AntHocNet, shows how to utilise each UAV's remaining energy to ensure maximum safety. Using IoT-enabled aerial vehicles in healthcare could boost operational efficiency and monitoring while making flying IoT a more intelligent application. Improved energy efficiency and overall network performance can be achieved using [14]'s modified ant colony optimisation.

2.3.6 Cluster-based Routing in Flying Adhoc Networks

Clustered UAV networks can significantly improve their overall performance, making this a powerful network management technique. They have been thoroughly analysed for their specific features, potential strengths, and shortcomings. It is possible to scale up a UAV network's benefits by clustering the UAVs. These benefits include increased reliability and energy economy, data aggregation and fault toleration, and improved connectivity and coverage. CBRPs will become more complicated and more frequently used as the number of nodes grows. Probabilistic and deterministic methods are the most common types of grouping. Using probabilistic models, the former generates the choice, while the latter is deterministic. The major goal of the probabilistic cluster method is to find the best route while increasing the network's service life. They can be subdivided into dynamic, bio-inspired and hybrid clustering methods. The CH can be determined more accurately using CBRPs, which are deterministic. Various methods exist in deterministic clustering, including weighted, fuzzy, heuristic, and compound clustering. Protocols are examined in terms of their operational behaviour, intrinsic qualities, technique, number of nodes, competitive advantages, disadvantages, and particular applications.

2.3.6.1 CBRPS Based on Probabilistic Clustering

Probabilistic cluster algorithms aim to find the best routing path while increasing the network's lifespan. Several probabilistic cluster-based routing methods select the CH at random.

2.3.6.2 CBRPs Based on Deterministic Clustering

Several measures are used to determine CH in deterministic CBRPs, including energy, proximity, centrality, and node degree. To gain information from other nodes, a node listens and exchanges messages with them.

2.3.7 Research challenges in Flying Adhoc Network Routing

FANET networks, despite recent advancements, still have limitations that may be important to their operation, depending on the application. Among the most important challenges to overcome to make FANET a reality are the search for solutions to the limitations imposed by energy consumption, which limits flight time, speed of connection and range of signal transmission by drones. Other factors, such as the mobility and storage capacity of the drones, can also affect the network's performance. In the following paragraphs, we'll outline possible solutions to these issues. Antennas with directional capabilities: Antennas for routers are typically omnidirectional in design. As a result, the signal broadcast by these antennas is distributed uniformly in all directions. However, when used in drones, the antenna's quality and energy consumption may not be very efficient. As a result, new antennas with beamforming technology have been created. This alteration allows the broadcast signal to be directed to a specified location around the UAV, as illustrated in Figure 4.6.1. Thus, the UAV's power consumption is lowered while the signal quality at the specified location is improved. However, because it is still a novel technology, further research and testing are needed before it can be implemented. In terms of mobility, unmanned aerial vehicles (UAVs) have a wide range of speed and mobility options, making it possible for them to fly to locations that are difficult to access or cover great distances quickly. It means that for one or more of the drones to be able to move around in a network, they must be able to send critical information to other drones in that network or to the base station, such as warnings about collisions and other hazardous conditions such as GPS location, flight time, and other weather-related factors, as shown in Figure 4.6.2. Although numerous routing protocols are already in existence, some cannot keep up with the mobility and speed of UAVs, resulting in a high rate of connection faults and, in some circumstances, the network dropping completely.

2.4 The Proposed (EA-CBRP-FAN) WBAN based IOMT Routing Protocol

Energy Aware Cluster based Routing Protocol for Flying Ad hoc Networks (EA-CBRP-FAN) is proposed. Figure 3 describes about the Routing framework of the proposed protocol. There are total four cells in the proposed framework Model. Each cell is divided into total four clusters. Each cluster consists of Cluster Member (CM) as Sensor Nodes. The CM sends the information to each cluster head (CH) with in each cluster. The CH are responsible to communicate with the Base stations (BS). The CM works as a Body Area Sensor Nodes. The CM nodes acts as medical Sensor Nodes and are deployed on the Human body. They are responsible to collect the vital parameters of the human body. The BS of the cells are connected with the Health care Application via a Cellular based Infrastructure. The Health care based Application is capable to share the patient health care information with doctors at remote location, with hospitals, Ambulances and Rescue Authorities. They Health care Application is surrounded by Internet of Medical things (IOMT) based Infrastructure. The Health care Application is also connected with Flying Ad hoc Networks (FANs) via Internet of Drones based Infrastructure (IODs). These FANs can provide rescue and emergency operations in transporting Emergency lifesaving medications at Remote locations, where emergency rescue operations cannot be performed in minimum amount of time via using road based Infrastructure.

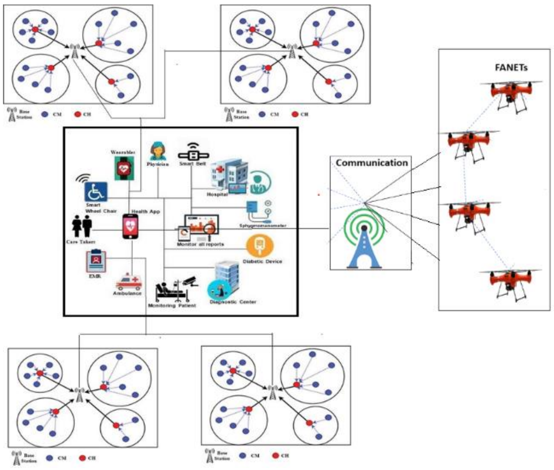

Figure 3: Proposed EA-CBRP-FAN Framework

Table 2 describes about the confusion matrix technique applied to ML technique. The ML technique which is used in this research work is Simple Neural Network [25]. The values for the confusion matrix are extracted from Table 2.

Table 2: Confusion Matrix Values Applied to ML Technique

ML Algorithm	True Positive (TP)	True Negative (TN)	False Positive (FP)	False Negative (FN)
Neural Network	3	3	4	4

Table 3 describes about the calculation of different performance measures using ML and deep learning techniques. Approximately 0.90 value had been achieved by using these performance measures.

Table 3: Performance Measure Calculation Using ML Techniques

ML Algorithm	Accuracy	Precision	Recall	F1-Score
Neural Network	0.42	0.42	0.42	0.419

III. Results and Discussion

Figure 3 describes about the graphical representation of ML technique based on confusion matrix. The parameters values which we had calculated numerically are Accuracy, Precision, Recall and F1-Score.

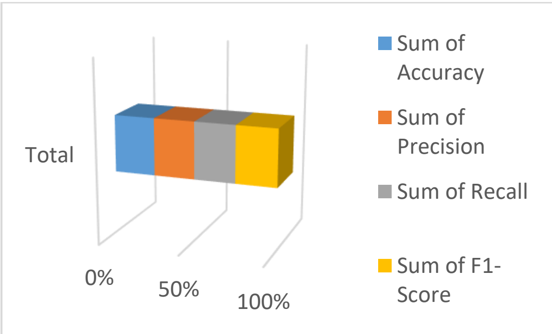

Fig 3: Graphical Representation of ML Technique

From the graphical results it has been observed that the numerical values of Sum of accuracy, Sum of precision, and Sum of recall are approximately equal. This means that in our case the performance of supervised Machine learning algorithms [27] are predicted performance at 42% accuracy in case of this scenario. This novel is case of real time dataset obtained from Drones using Thermal images.

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