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Communication in a Heterogeneous Ad Hoc Network

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***Abstract*—**Wireless networks are getting more and more used in every new technology or feature, especially those without infrastructure (Ad hoc mode) which provide a low cost alternative to the infrastructure mode wireless networks and a great flexibility for application domains such as environmental monitoring, smart cities, precision agriculture, and so on. These application domains present a common characteristic which is the need of coexistence and intercommunication between modules belonging to different types of ad hoc networks like wireless sensor networks, mesh networks, mobile ad hoc networks, vehicular ad hoc networks, etc. This vision to bring to life such heterogeneous networks will make humanity duties easier but its development path is full of challenges. One of these challenges is the communication complexity between its components due to the lack of common or compatible protocols standard. This article proposes a new patented routing protocol based on the OLSR standard in order to resolve the heterogeneous ad hoc networks communication issue. This new protocol is applied on a specific network architecture composed of MANET, VANET, and FANET.

***Keywords*—**Ad hoc, heterogeneous, ID-Node, OLSR.

I. Introduction

THE wireless ad hoc network is a wireless network decentralized (without infrastructure: router or access point). It is a spontaneous network, where each node can be considered both as a router and as a host. Based on the network connectivity, the choice of the node who forward data is made dynamically.

In the ad hoc network the nodes ignore the topology of their network. The routing protocol is the standard that assure for network devices the discovery of their environment by controlling which way to route packets. There are several types of routing protocols [1]:

- Proactive: maintains fresh lists of destinations and their routes by periodically distributing routing tables throughout the network,
- Reactive: finds a route on demand by flooding the network with Route Request packets,
- Hybrid: combines the advantages of proactive and of reactive routing,
- Flow Oriented Routing: finds a route on demand by following present flows,
- Hierarchical Routing Protocol: the choice of proactive and of reactive routing depends on the hierarchic level where a node resides,
- Back-pressure Routing: chooses next-hops dynamically as a packet is in progress toward its destination. These decisions are based on congestion gradients of neighbor nodes,
- Host specific Routing Protocol: requires thorough administration to tailor the routing to a certain network layout and a distinct flow strategy,
- Power-aware Routing Protocol: Energy required to transmit a signal is approximately proportional to distance and the attenuation.

The nodes characteristics and nature define the type of the network to which they belong. wireless Ad hoc networks include networks such as: WMN "Wireless Mesh Network", WSN "Wireless Sensor Network", MANET "Mobile Ad hoc Network", VANET "Vehicular Ad hoc Network" and FANET "Flying Ad hoc Network". Each network has its own concept and purpose to ensure the communication between their nodes.

The current research aims to develop an heterogeneous networks by improving their internal communication performances by studying and acting on different parameters, such as: routing protocols, self-organization, energy savings and security mechanisms. The definition of heterogeneity in ad hoc networks differs from researcher to other. In the literature, the studies deal with two combinations family:

- Network heterogeneity taking into account the nature of the nodes that compose it or the technology ensuring the communication within this network,
- Heterogeneous environment in gathering different types of network in the same one.

This article presents the second type of heterogeneous network, regrouping: MANET, VANET and FANET. We propose a new routing protocol assuring the communication between the different components of our heterogeneous network named "HAdN-MVF" (Heterogeneous Ad hoc Network MANET VANET FANET).

The remainder of the paper is organized as follows. In Section II, an overview of ad hoc networks types. In Section III, related work treats an idea about the current method of communication between the heterogeneous network components. Then, in Section IV, we propose a new solution of communication in heterogeneous network consisting of MANET, VANET and FANET. Finally, we conclude this paper.

II. Type of Ad hoc Networks

Self-configuration, self-organization and ease of use and flexibility present strong points of the ad hoc networks,

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making this type of network very useful in critical areas such as: Military, health, security road, agriculture, safety environmental and human. To benefit from these advantages and to meet the needs of use, the ad hoc networks are divided into several subsets:

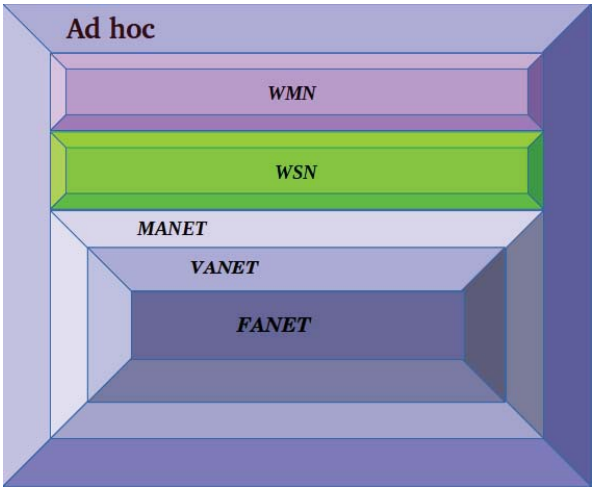


Fig. 1 Type of ad hoc network

A. WMN: Wireless Mesh Network

A wireless mesh network, as the name suggests is a radio communication network based on a mesh topology. The architecture of this network is mainly made up of: mesh clients usually mobile like laptops, mobile phones and other wireless equipment and mesh routers and gateways that are mostly fixed ensuring the exchange of data between nodes.

The routing protocol is needed to maintain and reconstruct the routes as mesh-client communication progresses. The majority of researchers have agreed that reactive on-demand routing protocols are more suitable for WMNs, such as: HOVER, AODV, WMR, [2].

By using alternative paths and multi-hop routing, WMN can overcome data transmission failures due to mobility, interference, and congestion, and can also increase the battery life of mobile nodes. Due to these and many other advantages, WMNs have been targeted at various applications such as disaster relief, metropolitan area networks.

B. WSN: Wireless Sensor Network

The wireless sensor network is a monitoring and tracking system composed of sensor nodes that are characterized by their intelligence, small size and economical side: cost, consumption of energy or power. WSN can be organized in two modes [3]: structured involves the deployment plan of Sensor nodes and unstructured the sensor node is deployed ad-hoc i.e communication without infrastructure between nodes. They are used in many areas: traffic control, vehicle detection, greenhouse monitoring, etc.

Each node of the WSN network consists of one or more sensors to collect physical or environmental parameters such as: pressure, humidity, temperature, and others depending on the field of application. Integrated processors to record and process recover data and low power radios that transmit this data to the user.

In an ad hoc mode WSN network, it is necessary to choose the correct routing protocol to ensure the transmission of data to the destination. According to the latest studies, the reactive routing protocols on-demand more precisely the AODV protocol works better in the WSN, it gives the best performances for example: end to end delay, throughput, and packet delivery ratio.

C. MANET: Mobile Ad hoc Network

MANET is a network composed of many free wireless nodes that can be transmitters / receivers or routers forming a dynamic topology without infrastructure that changes frequently and unpredictably. This type of network can operate autonomously or be connected to the Internet. a MANET network is composed of different devices such as: computer, PDA, mobile phone, etc.

since the 1990s, researchers have been trying to remedy and find relevant solutions to the problems and challenges of MANET networks linked to their decentralized nature and high mobility. To ensure reliable and robust communication between nodes when transmitting data, the best routing protocol must be chosen. the comparison studies between routing protocols of ad hoc networks: Proactive, Reactive and Hybrids, concluded that proactive protocols like OLSR make it possible to reach a better level of communication compared to other protocol families. But, we can say that the choice of protocol is related to the field of application and the performances that we want to ensure.

There are several applications for MANET such as military battlefield communications, search and rescue operations in disastrous situations such as earthquakes or information sharing during an interactive conference.

D. VANET: Vehicular Ad hoc Network

VANET is a special form of MANETs where the nodes are circulating in an intelligent road network with well organized infrastructure. VANET creates a mobile vehicular network with a wide range assuring three types of communication: Vehicle-to-Vehicle (V2V) and Vehicle-to-Roadside (VRC) or Vehicle-to-Infrastructure (V2I).

Each vehicle in the VANET architecture is equipped with a set of vendor-supplied applications installed in a device called an ”Application Unit” which can be single or multiple. ”AU” accesses the network only via the on-board unit ”OBU” presenting the communication core of the vehicle with its environment which includes other nodes (i.e other OBUs) and devices with waves called ”RSU” (Road-Side Unit) installed along the road network. ”OBU” provides the node with several services such as: wireless radio access, ad-hoc and geographic routing, network congestion control, reliable message transfer and data security. the ”RSU” equipment is fixed, connected to the backbone network and mainly exchanges security messages with ”OBU” [4].

According to recent studies, two large protocol families can provide communication within VANET networks: protocol based on the topology and protocol based on the geographical data of the nodes. But, according to the results of the different simulations made, the geographical protocols especially GPSR proved more reliable in term of result of routing and response time. The rest of the routing protocols (proactive: OLSR, reagent: AODV) remain with good performance and efficiency in the vehicular network.

VANETs are intended for a wide range of road network applications: vehicle safety, automated tolling, traffic management, enhanced navigation, Geo-localization services. a VANET node can transmit warnings about environmental hazards, traffic and road conditions and regional information to other vehicles.

E. FANET: Flying Ad hoc Network

FANET is a sub-family of MANET and VANET networks, consisting of unmanned aerial vehicles (UAVs) that require peer-to-peer connections for synchronization. drones are flexible, inexpensive and quick to deploy. The topology of FANET networks is special because it is characterized by a frequent change because of the high mobility of the nodes and a wide range of communication related to the large distance between its components. In this type of network, it is essential to collect data from the environment and send it to the command and control center. Therefore, FANET must provide peer-to-peer communication and converge broadcast traffic at the corresponding time. the drone networks are very interesting for many civil and military applications.

The dynamic topology of FANETs makes communication complex within this network, so the existing routing protocols designed for MANETs fail to follow changes in network topology. To remedy this problem, a study has proposed a new version of OLSR called P-OLSR (Predictive-OLSR) [5], it takes advantage of GPS information available at the node to predict the evolution of the quality of wireless links.

TABLE I
COMPARISON TABLE OF THE DIFFERENT AD HOC NETWORK

	Ad hoc network types				
Criteria	***WMN***	***WSN***	***MANET***	***VANET***	***FANET***
Node mobility	Low	Low	Low	Medium	High
Node density	High	High	High	Medium	Low
Topology change	Slow Steady	Slow Steady	Slow Steady	Average Speed	Rapid Speedy
Energy power	Need Limited	Need Limited	Need Limited	Not needed Average	Needed for small UAVs Very big
Locali-zation	GPS	GPS	GPS	GPS, AGPS, DGPS	GPS, AGPS, DGPS, IMU
Protocol	AODV	AODV	OLSR MPOLSR	QoS-OLSR	P-OLSR

III. RELATED WORK

A. An Inter-Domain Routing for Heterogeneous Mobile Ad Hoc Networks

In heterogeneous ad hoc networks (MANET, VANET and Mesh), the communication between its components (nodes) is impossible. Because, every network uses a routing protocol specific to its own environment. So, there is a lack of interoperability between the different routing protocols.

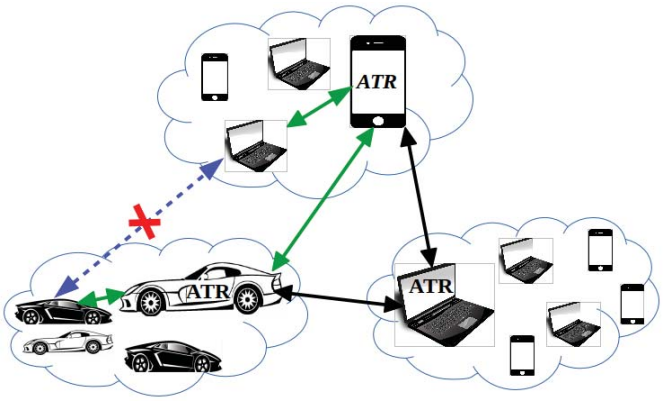


Fig. 2 "ATR" communication

ATR (Ad hoc Traversal Routing) is a solution which resolve the problem of communication between nodes component the heterogeneous network. Its principle is creating the connectivity between the heterogeneous nodes through gateways (ATR nodes: nodes that ATR is installed) that convert control messages from one network to another, and adding the node address of different networks into the routing table for routing protocols.

Each ATR node has two roles: node/router in its own network and gateway to allow its neighbors on the same network to exchange information (data) with nodes belonging to other types of network.

The converting mechanism in ATR node change according to type of routing protocol used:

- Reactive protocol (AODV): If the ATR node is a transmitter, it sends route request messages (RR) within its network (node/router role) and at the same time converts it (Gateway role) into a new route request message called ATR route request message (ATR-RR) for the different networks to transfer the route request messages to the neighboring ATR node of the different network. If the ATR node is the receiver node, it converts the ATR route request message to a route request message and sends both messages each one to its destination(ATR-RR to ATR nodes and RR to neighbors in the same network).
- Proactive protocol (DSDV): The ATR nodes collect the address information of the nodes in the network to which they belong and each ATR node shares this collected information with its neighboring ATR nodes. Then, the proactive protocol can create the route entry for nodes of different networks in the routing table.

- Position-based Routing Protocol(GPSR): Wherever the ATR node converts from position-based routing to proactive or reactive routing, it must transforms the position information to the hop number by estimating the hop number from the position between the nodes. when ATR node converts from proactive or reactive routing to position-based routing, ATR node includes its own position to the converted control messages for position-based routing.

IV. Our Contribution

A. Introduction

According to the communication technique dealt within last section, it was noticed that the ATR node during the conversion: loses energy, consumes memory space, requires a processing time and risks losing the link with its ATR neighbors (topology change). There is also a strong possibility of losing information if the source has no connection with the ATR node of its network.

To overcome disadvantages of ATR solution in heterogeneous network, we propose a new communication method ensuring the optimal, reliable and fast exchange data between the different components of heterogeneous network.

Our team (M3S: Mobile Smart Security Systems) is working at the network layer in ad hoc networks specifically MANET by choosing OLSR as a routing protocol and is trying to provide original solutions to meet the challenges of this type of network such as security ([7], [8]), mobility [9] and reduction broadcast redundancy [10].

The standard OLSR protocol is based on the exchange of Hello and TC messages. Each node broadcasts a Hello message (Fig. 3 (a)) to get an overview about its neighborhood. This message transmits several information and has several utilities such as: the type of link, the willingness of the node, information about the neighbors, etc. To build the routing tables, each node periodically sends in the throughout network a TC message (Fig. 3 (b)) containing the list of its neighbors.

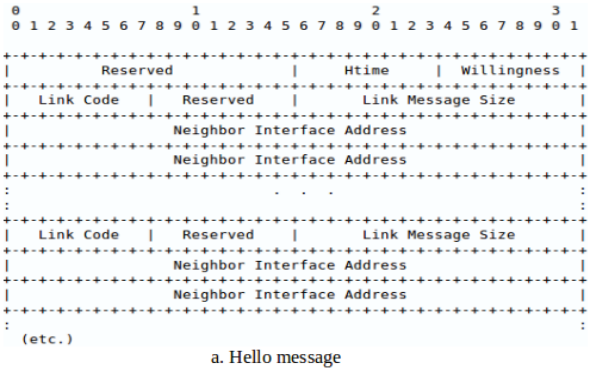
B. Solution Description

According to the comparison table (TABLE I) and the study done in Section II, we observe that the MANET, VANET and FANET networks are of the same family and use different versions of the same routing protocol ”OLSR”.

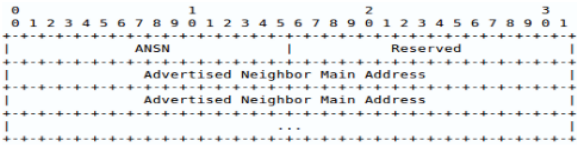
So, we decided to work on a heterogeneous network composed of these three networks, named ”HAdN-MVF” and we will assure the communication between its components by a new routing protocol based on ”OLSR standard”. This protocol allow to create a heterogeneous network with homogeneous nodes speaking the same slang while keeping the characteristics and properties of each node.

We propose a new version of OLSR called ”HAR-OLSR” (Heterogeneous Ad hoc Routing OLSR) intended for the network HAdN-MVF. In our patented idea[11], we propose a complete architecture of the new protocol contains many step acting on each other before sending the data:

In this article, we will treat the first step: identification of the node. For this, the protocol uses a new form of Hello



a. Hello message



b. Tc message

Fig. 3 Format of the original OLSR messages

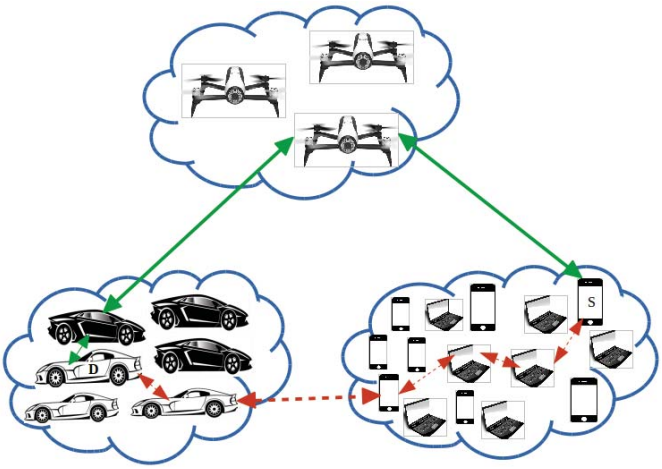


Fig. 4 ”HAdN-MVF” Communication

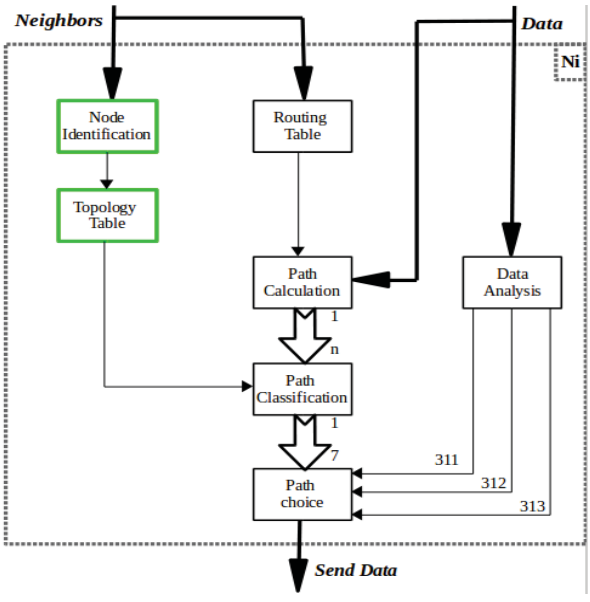


Fig. 5 New node communication architecture

and Tc messages integrating different parameters to ensure communication between the heterogeneous nodes constituting the network.

Byte 0 01234567	Byte 1 01234567	Byte 2 01234567	Byte 3 01234567
Reserved		Htime	Willingness
Altitude		Range	
Latitude			
Longitude			
Link Code	Reserved	Link Message Size	
Neighbor Interface Address			
Neighbor Interface Address			
...			

Fig. 6 New Hello message format

Fig. 6 illustrates the modified form of the Hello message where green colored bytes correspond to the added fields. We insert in this message all the information that will make it possible to specify the neighbor node type:

- The latitude and longitude as floating-point numbers occupying 4 bytes each.
- The altitude as a 16-bit fixed-point number.
- The signal range Range also represented in a fixed-point number reserving 16 bits.

The new form of the hello message affects the size of the standard message by adding 12 bytes regardless of the number of nodes in the network. The 802.11 frame encapsulates an IP packet that in turn encapsulates a UDP datagram containing the hello message. The additional 12 bytes are negligible overhead in relation to the total size of the frame in medium and large networks.

Byte 0 01234567	Byte 1 01234567	Byte 2 01234567	Byte 3 01234567
ANSN		Reserved	
Advertised Neighbor Main Address			
$V_{(i,j')}(t)$		ID_Node	
Advertised Neighbor Main Address			
$V_{(i,j'')}(t)$		ID_Node	
...			

Fig. 7 New TC message format

Fig. 7 illustrates the new structure of the TC message by adding three bytes reserved to:

- The average instantaneous speed $V_{(i,j)}(t)$ formatted as a fixed-point number occupying a block of 16-bit.
- The node identifier "ID-Node" represented in a fixed-point number reserving 8 bits.

To calculate the average instantaneous speed, we need the instantaneous relative velocity $\tilde{V}_{(i,j)}(t)$ between node i and its neighbor j at time t. Thus, the relative speed is calculated as follows:

$$\tilde{V}_{(i,j)}(t) = \frac{d_{(i,j)}(t) - d_{(i,j)}(t-1)}{\delta t} \quad (1)$$

where:

* $d_{(i,j)}(t)$ and $d_{(i,j)}(t-1)$ are the corresponding distances between the nodes i and j.

* δt : is the difference between the arrival time of the first and last message Hello.

The GPS coordinates accept the error. Thus, to be more precise in the computation of the instantaneous speed, we will calculate its average by using an α parameter representing an exponential average. Then, the speed is represented as follows:

$$\begin{cases} V_{(i,j)}(t) = \alpha \tilde{V}_{(i,j)}(t) + (1-\alpha) V_{(i,j)}(t-1), \ 0 \leq \alpha \leq 1 \\ V_{(i,j)}(0) = 0 \end{cases} \quad (2)$$

Every node of the network attributes an identifier to each there neighbors basing on there range and proportional velocity. The ID-Node takes three values 1, 2 and 3 representing MANET, VANET and FANET respectively. The choice of identifier respects the below organizational chart:

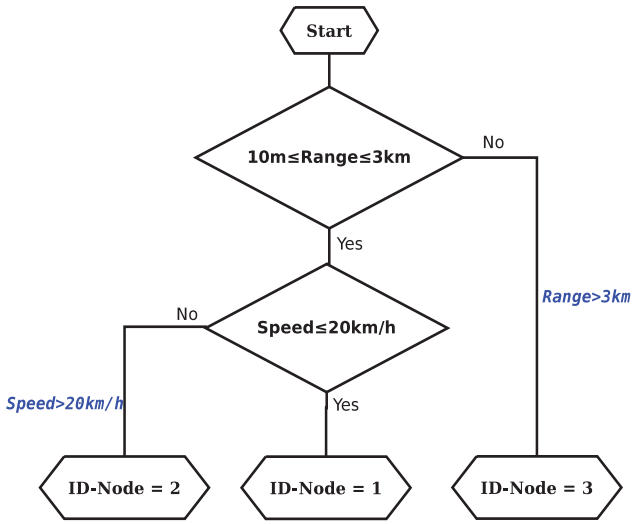


Fig. 8 Identification organizational chart

Each network has an unique characteristics with whom it is known like the speed and range of its components.

The choice of the range interval [10m, 3Km] that has been set as a condition for specifying the type of node is based on a simulation founded on the traces of the actual movement of the city bus fleet of the metropolitan area of Seattle, Washington on their regular routes providing bus passenger service throughout the city [12].

On the MANET networks, we can maximize the speed to 20 km/h by referring to the average speed of the marathon world record reached by Wilson Kiprotich in 2013.

V. Conclusion

In this article, we gave an overview of the different existing ad hoc networks and the problem of lack communication between them was disclosed. In the rest of the article, we studied a heterogeneous ad hoc network named HAdN-MVF,

composed of three types of ad hoc networks MANET, VANET and FANET (Fig. 4 illustrates the network HAdN-MVF). A new "HAR-OLSR" protocol based on the standard OLSR has been proposed for this type of network, the purpose of which is to ensure communication between the components of the heterogeneous network while respecting their natures.

HAR-OLSR is based on the identification of the neighbors by specifying the nature of their networks of membership and shared it in the whole network. The flowchart in Fig. 8 explains the principle of identifying nodes based on signal range and speed of the nodes. This identification maked to be used in the second step "Path Classification" of our main protocol (Fig. 5) in his multipath version.

In the next, we plan to implement this solution and analyze its impact on the following metrics: End-to-End Delay, Energy, Packet Delivery Ratio and throughput.

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