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A Performance Optimizing of VANET Communications

The Convergence of UAV System with LTE/4G and WAVE Technologies

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Abstract - With the bulky intensification of conventional vehicles on roads presently, driving has become more challenging and dangerous issue. Roads are filled up with vehicles, reasonable speeds and safety distance are rarely adhered to, and travelers frequently lack adequate concentration. As such, leading automobile fabricators decided to collectively work with government organizations to come out with solutions geared toward assisting travelers on highways by anticipating dangerous scenario or refrain from severe traffic regions. Hence, Vehicular communication systems has been come to existence.

Vehicular communication systems are networks in which smart ground vehicles and roadside units are the fundamental communicating nodes, providing each other with information, such as safety warnings and traffic information. Moreover, there are two basic types of communication approaches, V2V and V2I respectively. Even though, both approaches have their own constraints within various scenarios. For instance, V2V communication in highway scenario, to broadcast a delay-sensitive information such traffic accident warnings, it has entirely depended on the sparseness and swiftness of smart ground vehicles. Thus, it will be difficult to achieve the goal of safety applications due to intermittent connectivity. Additionally, each vehicle periodically broadcasts a beacon or hello message to each other that used to exchange their current states and surrounding info, consequently this, they have consumed a high bandwidth from limited VANETs spectrum (75 MHz). Whereas, V2I communication in urban and highway scenarios, the effectiveness of the communication between smart ground vehicles and roadside infrastructures mostly depends on the capability of roadside infrastructures. Therefore, it will be expected from VANETs technologists and authors to bring out pretty solutions for improvement of VANET communications and applications incorporate with the existing ones. In this paper, based on reviewed various literatures and related works, I have selected and integrated UAV system, LTE/4G and WAVE wireless access network technologies to optimize the VANET communications and satisfy some demands of its basic applications, particularly safety and traffic, in highway scenario.

This work proposed a converged novel architecture of UAV system, LTE/4G and WAVE technologies with its forwarding schemes in highway scenario to enhance the VANET communications and achieve some requirements of its basic applications, particularly safety and traffic. Algorithms for UAV's sensing, tagging (based on my proposed safety and traffic info model) and broadcasting operations, and forwarding of safety or traffic info to respective infrastructures and then smart ground vehicles are designed, particularly to minimize intermittent connectivity and high bandwidth usage, and as well as to satisfy some requirements of VANET applications.

Keywords - *VANET; UAV System; LTE/4G; WAVE; Converged Wireless Technologies in VANETs*

INTRODUCTION

Nowadays, car traffic accident is one of the leading causes of fatalities in our world. Thus, most of the developed countries have been centered on the vehicular communication systems. Vehicular communication systems **[1]** are networks in which smart ground vehicles and roadside units are the communicating nodes, providing each other with information, such as safety warnings and traffic information. They can be effective in avoiding accidents and traffic congestion. Both types of nodes are DSRC devices. DSRC works in 5.9 GHz band with bandwidth of 75 MHz and approximate range of 1000 m. Besides, vehicular communication is usually developed as a part of ITS and governing by the ISO/ETSI reference communications stack **[2]**. Generally, the communication mode of VANET classified into two, V2V and V2I respectively **[3]**. V2V has uses the OBU to communicate with one another, which enables distributed pattern of communication among vehicles with decentralized coordination. While V2I has vehicles communicate to RSU so as to enhance communication range by sending and receiving information from a vehicle to another vehicle. However, these two types of VANET communications have their own constraints within various scenarios. For instance, V2V communication in highway scenario, to broadcast a time-critical information like traffic accident warnings, it has completely depended on the sparseness and swiftness of vehicles. Thus, it will be difficult to achieve the goal of safety applications due to intermittent connectivity. Additionally, each vehicle periodically broadcasts a beacon or hello message to each other that used to exchange their current states and surrounding info, consequently this circumstance, they have consumed a high bandwidth from limited VANETs spectrum (75 MHz). Whereas, V2I communication in urban and highway scenarios, the effectiveness of the communication between smart ground vehicles and roadside infrastructures mostly depends on the capability of roadside infrastructures. Thus, it will be expected from VANETs technologists and scholars to bring out pretty solutions for these types of constraints incorporate with the existing ones.

In this paper, to provide the performance enhancement of VANET communications and satisfy some requirements of its basic applications (safety and traffic) in highway scenario, a converged novel architecture with its forwarding schemes have developed. The architecture designed based on make a convergence of UAV system with LTE/4G and WAVE wireless access technologies, and as well as I have developed a few algorithms for UAV system operations which sensing, tagging and broadcasting the current states of vehicles information either safety or traffic, and forwarding schemes to respective infrastructures and smart ground vehicles.

RELATED WORK

A. VANET Communications Using LTE/4G

In **[4]** a performance evaluation of LTE and IEEE 802.11p for VANETs has been conducted. The paper presented a detail performance evaluation study between LTE and IEEE 802.11p for VANETs based on a variety of parameter settings such as beacon transmission frequency, vehicle average speed, and vehicle density. This comparison between LTE and IEEE 802.11p was performed in terms of delay, reliability, scalability, and mobility support in the context of various applications requirements like safety, traffic management and infotainment.

The authors have proposed two architectures to compare vehicular networking that utilizes whether IEEE 802.11p-based infrastructure-less network or infrastructure-based LTE cellular network. In these architectures, LTE eNodeB and RSU have deployed on the road side. Besides, the vehicles which IEEE 802.11p-enabled can use WAVE interface between V2V and V2I whereas to use LTE eNodeB, the vehicles should have whether LTE-OBU or drivers must have a smart phone with LTE connectivity.

Based on their simulation results, the LTE standard offered superior network capacity and mobility support as compared with IEEE 802.11p standard. In order to this, the LTE technology is suitable for most of applications. On the other side, IEEE 802.11p standard provided acceptable performance when lower vehicle density, traffic load, and vehicle speed. Although the work has not been considered a QoS-based scheduling algorithms for LTE technology. Furthermore, the study considered only the downlink-unicast communication, thus further exploration on downlink-broadcast is needed.

B. VANET Communications Using UAV System

The work in **[5]** proposed a network model that use a single UAV between a VANET segments to improve the VANETs connectivity and network efficiency. The proposed network model presented a UAV in the form of queuing system. The model consists of G_n groups of smart ground vehicles, UAV (queuing) system, which is static and at some point on **h** height. The group of vehicles interact with UAV via radio channel. And also *R-value* describes the radius of the possible interaction between UAV and smart ground vehicles, which depends on the height *h* of UAV flight. However, the model doesn't take into account the terrain and weather conditions.

The proposed network model has been explained in calculation and simulation approaches. During calculation approach, the authors are calculated the average data delivery time from vehicle to UAV, and the average service request time to UAV regarding on the arrival intensity of the service requests and service rate of requests.

Generally, the study results revealed that the UAV node acted as the same vehicle node that being between two vehicle nodes in VANETs. The vehicles can get an efficient service (connectivity) through UAV but it depends on the radius of the service UAV, data rate of the channel, length data and messages. While increase a number of vehicles in group affects transmission quality of data.

DESIGN OF THE PROPOSED SOLUTION

As I have discussed in related work, and generally, most of current VANET works deals with different aspects of wireless access technologies as whether separately or integrally for improvement of VANET communications, though there has not been any work that describes and presents adequately about the converging of UAV, LTE and RSU (DSRC/WAVE) networks architecture to optimize the performance of VANET communications and satisfy the basic VANET applications requirement in highway scenario regarding to connectivity and scalability to have a better QoS communications and applications. Thus, to provide an efficient communications and applications in vehicular ad hoc network, I have designed a new architecture that considered the above mentioned different wireless access networks.

Architectures of the Proposed Solution

I describe and present the overall architecture of my proposed system in a highway environment as shown in Figure 1.1 and 1.2. In section **I**, I describe and present my proposed UAV's periodically sensing, tagging and broadcasting operations of vehicles information in highway environment with MAVLink packets. In section **II**, approaches and objectives of forwarding models of the sensed information (tagged packets) to the respective wireless access network infrastructures via UAV's GCS are discussed. Propagating scheme of the sensed information to the target smart ground vehicles is demonstrated in section **III**. And finally I discuss and present my general proposed architecture states as shown in section **IV**.

Figure 1.1 shows the general low-level architecture of the proposed system in a highway scenario. In this low level architecture, I have designed three fundamental wireless network infrastructures (UAV, LTE/4G and RSUs) with their respective positions and I have assumed that the transmission range of each infrastructure and smart ground vehicle has considered as an ideal cell.

I have assumed that my single small UAV system is a full autonomous Quadrotor Drone (4 Rotor wing) type that does not require any direct human intervention for flying (uplink communication) and it capable to hover on a specific area for a while. The system has deployed on the middle highway segment with around 10m altitude (height) of UAV flight from the ground and its transmission range covered nearby 150-200 meter, and completely confined by the transmission range of LTE/4G. The drone has a hovering motion over the area of sensing operation and proceed a different types of communications such as with smart ground vehicles and LTE/4G via IEEE 802.11b/g interface with the help of its CCT BS/GCS.

In my proposed architecture, I have only used a downlink communication that a UAV broadcasts the sensed information (tagged packet) within transmission range. In order to this, the drone on-board vehicles and GCS will receive the broadcasted packet via LOS or direct radio link of IEEE 802.11b communication. Besides, the GCS that present in the proposed model has also used as a gateway to make a communication between UAV and LTE/RSUs.

Whereas the LTE/4G network has designed on the highway segment as one of the wireless access network infrastructures. I supposed that the eNB cell covered about 1km which means it can completely cover the transmission range of the other deployed infrastructures as shown in Fig 1.1. The network can communicate with the UAV system through its core network (EPC server). Likewise, the LTE/4G network can make a direct communication with E-UTRAN on-board mounted vehicles (driver's LTE equipped cell phone) when those vehicles being in the eNodeB cell.

Two RSUs (DSRC/WAVE) have also designed as a left and right sides of UAV system respectively. I have thought that each RSU has about 250 to 300m coverage area and absolutely confined by LTE/4G transmission range as like as UAV system. They are also connected with UAV system via Internet or their own gateways and can proceed a communication. Moreover, the infrastructures can make direct communications with WAVE-enabled vehicles via IEEE 802.11p wireless interface when those vehicles being in the RSUs coverage area. Furthermore, I have also considered a few basic assumptions when I design the proposed architecture. Such as, a deployment distance between infrastructures, the flow and transmission range of vehicles, and street type.

I have supposed that the deployment distance between RSU 1 (the left one) and UAV, and again between UAV system and RSU 2 (the right one) have about 180 and 300 meter respectively. However, the deployment distance of eNB is not compulsory because it has a high coverage area than others, thus I have thought that wherever eNB deployed, it has not any significant effect in the proposed architecture. Though, to better clarification of the proposed system, I have simply deployed the eNB about 80 meter far away from RSU 1 (the left one). While I have assumed that the transmission range of vehicles is less than the range of remaining deployed wireless access infrastructures and it varies from vehicle to vehicle as shown in Fig 1.1. And also the vehicles highly exposed for intermittent connectivity due to a highway scenario and their own dynamic movements. Additionally, I have considered the street type as a two lane highway with different flow of directions which means on the upper lane, the flow of vehicles proceeds from right to left whereas on the lower lane, it proceeds from left to right as demonstrated in Fig 1.1.

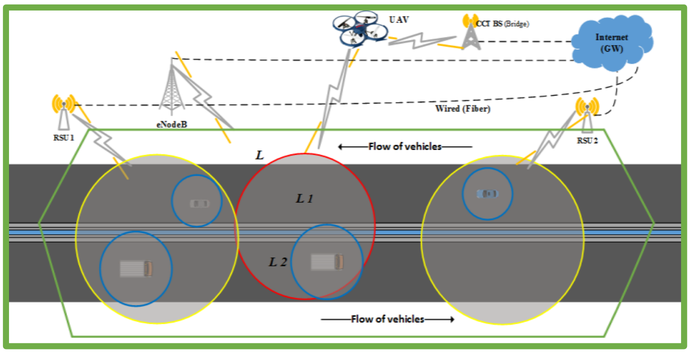

Figure 1.1: General Low-Level Architecture of the Proposed Solution

Fig 1.2 that shown on the below depicts the overall high-level architecture that will be implemented in the proposed system in a highway scenario. Generally, the architecture has four core modules those are Unmanned Aerial Vehicle (UAV), Long Term Evolution (LTE/4G), Road Side Unit (RSU 1/RSU 2) and Smart Ground Vehicle modules. And also there are four proposed forwarding schemas that from UAV (GCS) to LTE/4G, UAV (GCS) to RSU 1/RSU 2, LTE/4G to Smart Ground Vehicles and RSU 1/RSU 2 to Smart Ground Vehicles respectively.

In the UAV module, there are four fundamental layers such as application, network and transport, processing unit, and communication layers correspondingly **[6, 7]** as revealed in Fig 1.2 as shown below. The communication layer has capable to transmit and receive various data from/to other UAV and/or GCS via IEEE 802.11 b/g based RF transceiver. In the processing unit layer, there are three major internal modules such UAV Controller (FCS), Task/Mission Manager and Sensor Unit. The primary operation of UAV controller is reads and analyzes data from a wide variety of sensors and produces a mission flight plan, and it has direct communications with sensor unit and task manager modules. Task/Mission Manager module is responsible for registering new and monitoring ongoing missions, and it has three direct communications such with sensor unit module, task manager module and communication interface layer. The third module of processing unit layer is a sensor unit which responsible for detecting and measuring a different stimulus and signal of UAV's internal part and sensing operation area. In this module, there are many well-known sensors are installed, such as GPS for navigating a position of UAV and operation area, Accelerometer for detecting the velocity of UAV and the moving objects those being in the operation area and HD Video/Photo for capturing a high quality pictures and videos from operation area. The network and transport layer of UAV is a fundamental layer that primarily responsible for routing a MAVLink packet **[8]** and end-to-end communication via UDP or TCP/IP respectively. Whereas, the last layer of UAV module is application layer that accountable for supporting and providing different services such as mapping, surveying, traffic controlling, military operation and border monitoring. However, those applications are depending on the type and capacity of UAV.

As presented in Fig 1.3, the LTE/4G module **[9]** has two major components which named as eNodeB (eNB) and EPC server respectively. The eNB is a fixed base station that has E-UTRAN interface and it can transmit and receive a data from/to LTE-enabled devices via its own transceiver antenna within a cell. Whereas, EPC server has encapsulate the core network of LTE which includes S-GW and PDN-GW. Besides, when a downlink communication proceeds, the packet will be EPS bearer by EPC server.

The Smart Ground Vehicles module that is demonstrated in Fig 1.3 has six basic layers. They are applications, facilities, network & transport, communication media, management and security. The communication layer is responsible to make a connection with smart vehicles and different wireless access technologies via their own different wireless/wired external interfaces. Mostly the OBU of communication media consists of Ethernet, GPS, WiFi, 2G/3G and IEEE 802.11p external interfaces. In the proposed work, the smart ground vehicles have LTE/4G, IEEE 802.11p and IEEE 802.11b/g external communication interfaces. Moreover, this layer can communicate with the management and security layers of OBU via management and security internal interfaces respectively, and also it has communication with network and transport layer through the internal network interface. The second layer, network and transport layer, has comprised different protocols such as GeoNetworking protocol, TCP/UDP and IPv6 mobility extensions. The primary function of the layer is to make a routing, IP mobility and an end-to-end connectivity. Generally, it has a communication with management, security and facilities layers through management network, security network and network facilities internal interfaces respectively. While the facilities layer is accountable for supporting application, information and session/communication. Moreover, it has a direct communication with management, security and application layers. The upper layer in OBU of smart ground vehicles is application layer that is responsible for providing different applications for drivers and/or passengers in a suitable manner such as a road safety, traffic efficiency and infotainment. As other stated layers, application layer has direct communications with management, security and facilities layers. The last two layers of smart ground vehicles module are management and security layers. Management layer is considered as a cross-layer and it has a direct communication with all the remaining layers except security layer. Basically, it provides a management information base (MIB) services such as regulatory, cross-layer, station and application managements. Whereas, the security layer is also considered as a cross-layer and it offers a hardware security module, firewall & intrusion management, authentication, authorization and profile management, and also security management information base (identity, crypto-key and certificate management) services. Besides, it has direct communications with all the remaining layers except management layer.

RSU 1/RSU 2 module is the last module that resides in the proposed overall high-level architecture and it has almost identical components with smart ground vehicles except for the communication media which supports only IEEE 802.11p (DSRC/WAVE). Furthermore, the module is implemented on the static infrastructures (RSUs) rather than dynamic objects (vehicles).

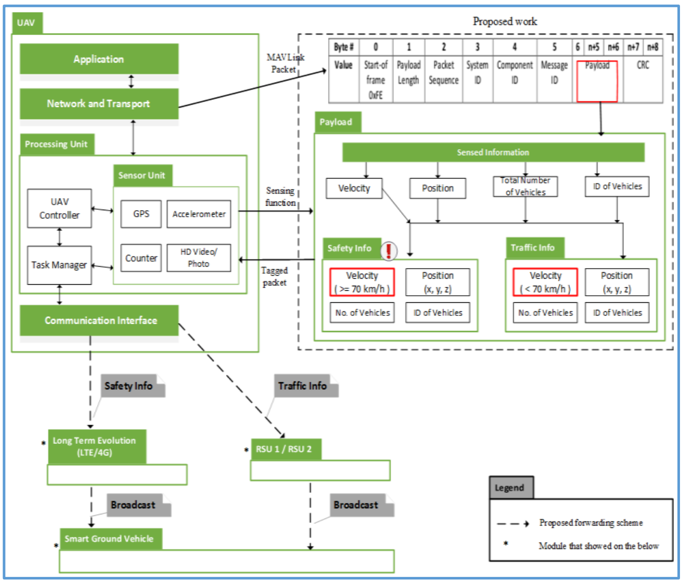

Figure 1.2: General High-Level Architecture of the Proposed Solution

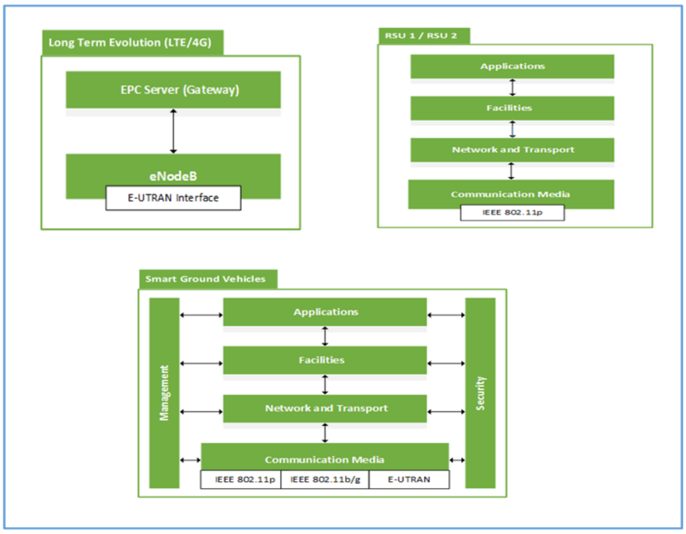

Figure 1.3: The Remaining Modules in General High-Level Architecture of the Proposed Solution

I. The Proposed UAV's Periodically Sensing, Tagging and Broadcasting of Vehicles Information

In this section, I have designed a single small UAV's periodically sensing, tagging and broadcasting operations of the current states of drone-mounted vehicles info within UAV coverage area to minimize a bandwidth consumption of vehicles that periodically broadcast their current states to other nearest vehicles and RSUs. Next, I discussed each UAV's proposed operation as follows.

A. Periodically Sensing Vehicles Info in Highway Environment

In this first task of the proposed high-level architecture model, I assumed that any vehicle within the highway scenario doesn't broadcast any sensed highway environment information to their surrounding vehicles and wireless access infrastructures. However, the vehicles can use the information for its own purpose if they want. In other word, there is no direct V2V and V2I uplink communications in the proposed system. Actually, the assumption is partially deduced from the theory of a high swiftness and sparseness of smart ground vehicles in highway environment **[3], [1], [10], [11]**. In this theory, to minimize the intermittent connectivity (to enhance V2V communication), it has used a direct V2I uplink communication. However, in the proposed work, I have excluded the direct V2I uplink communication and substituted it by UAV System and V2I downlink communication.

As I have demonstrated in Figure 1.2, the proposed architecture model is designed to overcome the above mentioned problems by using UAV's different sensors function from the sensor unit for detecting the different states of vehicles within UAV's transmission range. In this work, I have interested to periodically sense the speed, position, total number and ID of smart ground vehicles in UAV's transmission range. To achieve this, the UAV will periodically broadcast a beacon or Hello message to on-board drone vehicles within its transmission range, and if the message is received by the vehicles then I will use a UAV's GPS, Accelerometer and counter functions to detect current position, speed, total number and ID of smart ground vehicles respectively. As shown in Fig 1.1, the UAV's transmission range has covered both lanes, thus the vehicles those being in those tracks within UAV's transmission range would be detected by UAV's sensors. And the detected information will be organized as safety or traffic information and stored in a payload of MAVLink packet as I have discussed as follows.

B. Tagging a Sensed Information in a MAVLink

After completing the UAV's sensing operation, the sensed information will be tagged in a MAVLink packet via UAV. In this tagging operation phase, I will organize the sensed information as for safety or traffic information/application. To proceed the organization process, I have proposed a model that helps us to arrange the sensed information in an easy manner. Additionally, this proposed model is not only significant for arranging the sensed information even it is very compulsory for forwarding the information to the respective wireless access network infrastructures as shown as in Fig 1.4.

- **The Proposed Model of Safety and Traffic Information**

Generally, in the proposed model, any periodically sensed information in the coverage area of UAV have always the speed, position, total number and ID of smart ground vehicles. Then based on this circumstance, I have proposed a model of safety and traffic info that used to organize the information as safety or traffic info and optimize the forwarding of the information to the target wireless access network infrastructures (LTE/RSUs). I have discussed this proposed model in details below.

I have assumed that the total sensed information within transmission range and sensing interval time of UAV from both lanes denoted by **L** and the total number of sensed smart ground vehicles which detected from upper and lower lanes within the same coverage area and sensing interval time symbolized by **L1** and **L2** respectively as shown in Figure 1.1 and 1.4. Moreover, the total number of sensed smart ground vehicles those being in the coverage area of UAV denoted by **V**. And as I have demonstrated in Fig 1.1, the transmission range of UAV is considered as ideal or circle thus the area of transmission range is equivalent to πr^2. Therefore, I have inferred that the total sensed information is equivalent to the total number of sensed smart ground vehicles per UAV's coverage area as shown in **EQ. 1.1**.

$$L = V/\pi r^2 \quad \text{................ } (EQ.\ 1.1)$$

Furthermore, I have assumed that **L** is equivalent to the summation of the total number of sensed smart ground vehicles on upper and lower lanes as shown in **EQ. 1.2.**

$$L = L1 + L2 \quad \text{.............. } (EQ.\ 1.2)$$

As I have stated above, any sensed information within sensing interval time and transmission range of UAV always contains the speed, position, total number and ID of smart ground vehicles. Consequently, **L** contains all of this information. Then, on the basis of this circumstance, I have proceeded the organization process of the sensed information as safety or traffic information.

Based on VANET environments, safety warning speed has considered as one of safety applications. So, I have assumed that the speed of vehicles that beyond from the reasonable one, it may be a cause of collision/collision warning. So, in the information arrangement process, I have assumed that the reasonable vehicle speed in the proposed work is less than 120 km/h. Therefore, if there is any vehicle's speed from **L1** and/or **L2** which greater than or equal to 120 km/h, **L** will be classified as a safety information and tagged in the Safety Info module of the proposed work in the payload of MAVLink packet. Whereas if the speed of all vehicles from **L1** and/or **L2** is less than 120 km/h, **L1** and/or **L2** will be classified as a traffic information and then tagged in a different Traffic Info module if there is **L1** and **L2**. Else tagged in single Traffic Info module if there is only **L1** or **L2**. This last tagging process is very significant when during forwarding traffic information to RSUs as shown in Fig 1.4.

After accomplishing the tagging process, the UAV will broadcast the tagged packets within its own transmission range.

Algorithm 1.1 shows the pseudo code of UAV's sensing, tagging and broadcasting operations of vehicles info in the highway environment.

Input: *Vehicles n*

Process:

1. *UAV (Drone) broadcast a beacon message in every 0.5 second within its own range*
2. ***While** (Vehicle (on-board drone) received a beaconed message) **Do***
3. *Drone sense a current position of vehicles // by GPS*
4. *Drone sense a current speed of vehicles // by Accelerometer*
5. *Drone sense a current total number and ID of vehicles // by counter*
6. ***IF** (the current speed of one of vehicles >= 120 km/h) // from L1 and/or L2*
7. *The Drone tag all of the above sensed information in Safety Info module // L*

```
        Drone broadcast the tagged packet within its own
        coverage area
    ENDIF
    ELSE
        IF (the current speed of all vehicles < 120 km/h)
        // from L1 and/or L2
            IF (L1 && L2 exist)
                The Drone tag L1 and L2 in different
                Traffic Info Modules
                Drone broadcast the tagged packets within
                its own coverage area
            ENDIF
            ELSE
                IF (L1 || L2 exist)
                    The Drone tag L1 or L2 in a single
                    Traffic Info Module
                    Drone broadcast the tagged packet
                    within its own coverage area
                ENDIF
        ENDIF
    ENDWhile

Output: Vehicles Info in highway environment is sensed, tagged and
        broadcasted in a MAVLink packet
```

Algorithm 4.1: Algorithm for UAV's Sensing, Tagging and Broadcasting Operations of Drone-mounted Vehicles Info

II. THE PROPOSED FORWARDING MODEL OF THE TAGGED INFORMATION TO INFRASTRUCTURES

After accomplished the operations of sensing, tagging and broadcasting information by UAV, the actual forwarding of the sensed information to the respective infrastructures will proceed via UAV's GCS. In this phase, I have used one of the above models of tagged information which capable to optimize the forwarding schemas as shown in Figure 1.4, Algorithm 1.2 and Algorithm 1.3. I have discussed the forwarding process as follows.

After UAV broadcasted the tagged information within its own transmission range, the drone-mounted ground vehicles and GCS within UAV's transmission range will receive the broadcasted packet via LOS or direct radio link of IEEE 802.11b communications. Then the GCS will proceed again the inspection process that the received packet as for whether it is safety or traffic information depending on the packet's tagged vehicles speed.

If there is a safety information that a high vehicles speed from the accepted one (120 km/h), the GCS will forward it to the LTE-enabled vehicles through the LTE/4G core network to satisfy the nature of the information/application that required a high data rate and coverage area as shown in Fig 1.4 and Algorithm 4.2. During this forwarding process, the tagged packet will be an EPS bearer deliberately by EPC server or LTE/4G core network because the eNB has only process and propagate an EPS bearer packets within its own cell.

Whereas, if there is a traffic information that the speed of all vehicles is less than the accepted one (120 km/h) in **L1** and/or **L2**, the GCS will forward the information to the respective RSUs. In other word, if the GCS will receive **L1** in a single MAVLink packet, then GCS will only forward it to RSU 2 as shown in Fig 1.4 and Algorithm 4.3 because **L1** is most mandatory for smart ground vehicles moving from right to left and found within a coverage area of RSU 2. While if the GCS will receive **L2** in a single MAVLink packet, then GCS will only forward it to RSU 1 as shown in Fig 1.4 and Algorithm 4.3, because **L2** is most significant for smart ground vehicles those moving from left to right and being within transmission range of RSU 1. Otherwise, if the GCS will receive **L1** and **L2** in different single MAVLink packets, then GCS will forward **L1** to RSU 2 and **L2** to RSU 1 concurrently. Generally, I have assumed that proposed forwarding schemes of traffic information to RSUs will minimize the bandwidth usage when the RSUs broadcast the information to WAVE-enabled vehicles within their own coverage areas.

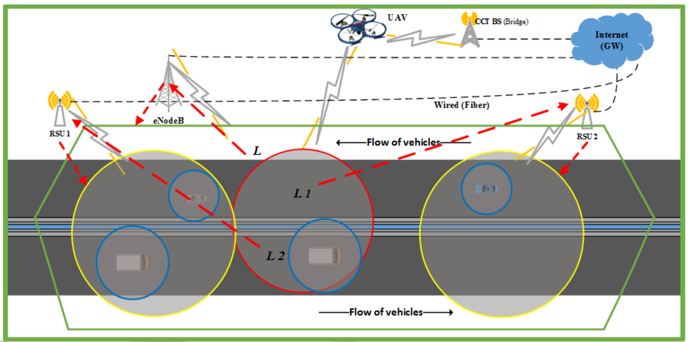

Figure 1.4: The Proposed Forwarding Schemes of the Sensed Information (Tagged Packets)

III. PROPAGATING THE SENSED INFORMATION TO THE TARGET SMART GROUND VEHICLES

As demonstrated in Figure 1.4, propagating the forwarded Information to the target smart ground vehicles is designed.

When a GCS forward a safety information to 4G-enabled vehicles via EPC server or LTE/4G core network, the eNodeB will be used to broadcast the information with EPS to the 4G-enabled vehicles within the eNB cell as shown in Fig 1.4 and Algorithm 4.2. In order for this, all 4G-enabled vehicles present in eNB cell will receive the safety information. In VANET environment, the safety applications require a high data rate and coverage area because they are delay-sensitive applications. Besides, in related work I have discussed that LTE/4G network has a high data rate and coverage area. Due to this, the proposed safety info forwarding model will realize the above mentioned circumstances.

Whereas, when a GCS forwards a traffic information to RSUs, the RSUs will broadcast the information to the WAVE-enabled vehicles found in the coverage area of RSUs. In other word, when GCS forwarded **L1** to RSU 2, then the RSU 2 will immediately broadcast it to WAVE-enabled vehicles within its own transmission range. While, when GCS forwarded **L2** to RSU 1, the RSU 1 will instantly broadcast it to vehicles within its own coverage area. Otherwise, when GCS simultaneously forwarded **L1** and **L2** to RSU 2 and RSU 1 respectively, then the RSU 2 will broadcast **L1** and RSU 1 will broadcast **L2** to vehicles within their own transmission ranges as shown in Fig 1.4 and Algorithm 4.3.

Algorithm 4.2 shows the pseudo code of the proposed forwarding and propagating schemas of safety information to the target 4G-enabled vehicles.

Input: *Vehicles n*

Process:

1. ***While*** *(GCS received the broadcasted tagged packet from UAV)* ***Do***
2. ***IF*** *(the speed of vehicle >= 120 km/h) // check L by GCS*
3. *GCS forward the tagged packet (L) to all LTE/4G-enabled vehicles via EPC server and eNB cell*
4. ***ENDIF***
5. ***ENDWhile***

Output: *The safety information is broadcasted to all LTE/4G-enabled vehicles*

Algorithm 4.2: Algorithm for Forwarding and Broadcasting of Safety Info to 4G-enabled Vehicles

Algorithm 4.3 shows the pseudo code of the proposed forwarding and propagating schemas of traffic information to respective RSUs and WAVE-enabled vehicles respectively.

Input: *Vehicles n*

Process:

1. ***While*** *(GCS received the broadcasted tagged packet from UAV)* ***Do***
2. ***IF*** *(the speed of all vehicles < 120 km/h) // L1 and/or L2*
3. ***IF*** *(the broadcasted packet is L1 only)*
4. *GCS forward L1 to RSU 2*
5. *RSU 2 broadcast L1 to WAVE-enabled vehicles within its own transmission range*
6. ***ENDIF***
7. ***ELSE***
8. ***IF*** *(the broadcasted packet is L2 only)*
9. *GCS forward L2 to RSU 1*
10. *RSU 1 broadcast L2 to WAVE-enabled vehicles within its own transmission range*
11. ***ENDIF***
12. ***ELSE***
13. ***IF*** *(the broadcasted packets are L1 and L2)*
14. *GCS forward L1 to RSU 2 and L2 to RSU 1 simultaneously*
15. *RSU 2 broadcast L1 and RSU 1 broadcast L2 to WAVE-enabled vehicles within their own transmission ranges*
16. ***ENDIF***
17. ***ENDIF***
18. ***ENDWhile***

Output: *The traffic information is forwarded and broadcasted to respective RSUs and WAVE-enabled vehicles*

Algorithm 4.3: Algorithm for Forwarding and Broadcasting of Traffic Information to Respective RSUs and WAVE-enabled Vehicles

IV. THE PROPOSED GENERAL ARCHITECTURE STATES

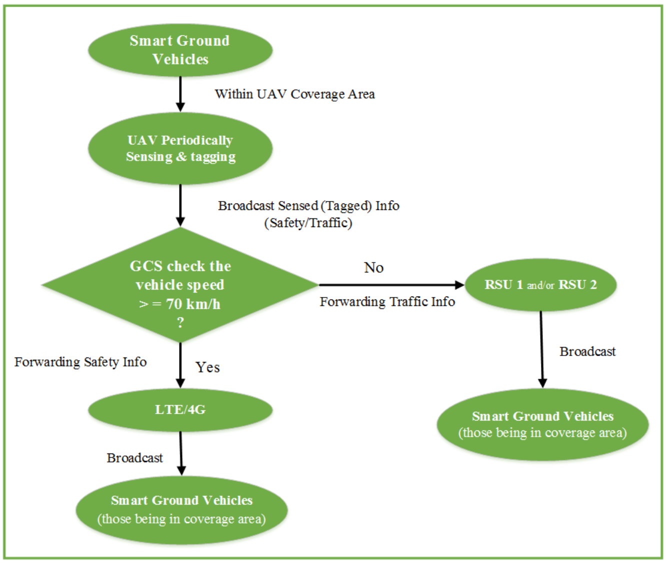

Figure 1.5: The Proposed General Architecture States

Fig 1.5 demonstrates the states of the proposed general architecture that will be implemented as the general proposed system. In these states, the smart ground vehicles are considered as the main input to proceed the UAV's sensing and tagging operations. As I have shown in the figure when the smart ground vehicles present in the coverage area of UAV then the operations of UAV's periodically sensing and tagging will be continued. The UAV senses the current states of smart ground vehicles (on-board drone vehicles) by using its different sensors, specifically GPS, Accelerometer and Counter. After sensing operation accomplished, immediately the tagging operation will be proceeded based on the proposed model of safety and traffic information as I have discussed in Section B. When the UAV finished the tagging process, it will broadcast the tagged packet within its own coverage area.

CONCLUSION

I have discussed the designed proposed solution in highway scenario that the integration of UAV System with LTE/4G and WAVE wireless access network technologies in order to improve the VANET communications and satisfy its basic applications (safety/traffic) requirement. For the next, I will simulate the designed architecture via suitable simulation environment and I will verify it that is essential for highway scenario.

FUTURE WORK

Though I did my best to realize the proposed integrated novel architecture with its forwarding schemes for VANET communications in highway scenario with the objective of overcoming the limitations of existing work (the basic principle of VANET communications in highway scenario), I do not trust that the architecture is standard enough to incorporate potential matters in VANETs highway scenario. For example, despite the importance of the issue, I have not considered the security and privacy aspect of the VANETs in my architecture since it was beyond the scope of this work. Thus, I hope that the proposed integrated architecture can be enriched in such a way that the security of VANETs is taken into account.

Regarding forwarding schemes, I have not considered/implemented a geo-cast forwarding scheme for RSUs to overcome the bandwidth consumption when the RSUs (RSU 1 and RSU 2) broadcasts the traffic information to WAVE-enabled vehicles within their own coverage areas (both lanes). For better clarification, by using geo-cast forwarding scheme, RSU 1 forwards a traffic information (L2) to lower lane only within its own transmission range, and as well as RSU 2 forwards a traffic information (L1) to upper lane only within its own transmission range. Therefore, I believe that the proposed integrated novel architecture with its forwarding schemes can be enriched in such a way that the geo-cast forwarding scheme on RSUs is taken into account.

Regarding infrastructure deployment consideration, I have not considered an optimal deployment of many UAVs (Drones) to proceed UAV's operations (sensing, tagging, and broadcasting of the current states of on-board drone vehicles information within UAV coverage area) on different areas of highway. Hence, I hope that the proposed integrated novel architecture can be enriched in such a way that the optimal deployment of many drones on different areas of highway is taken into account.

Furthermore, concerning with scenarios, I have not considered the implementation of my integrated architecture in urban scenario. Thus, I trust that the proposed integrated novel architecture can be enriched in such a way that the implementing/deploying the proposed architecture in urban scenario is taken into account.

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