A survey on the use of WiMAX and Wi-Fi on Vehicular Ad-Hoc Networks (VANETs)

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Abstract. With the continuous development of wireless communication technology and vehicle industry VANET as of recent is one of the most research niches. VANET is a technology that makes use of motion vehicles as a node in a network for the creation of a mobile network. Although there is a close characteristic between VANET and MANET (Mobile Ad-Hoc Networks), VANET has special features that differentiate it from MANET. VANET offers a vehicle to vehicle and vehicle to infrastructure communication. VANET also make sure there is no break of routing path before the transmission end. VANET is a challenging domain that has created a platform for many applications to find their place. Enough time is still needed for the implementation of large-scale practical though this field has been under rigorous study for over two decades. The possibility of having vehicular connectivity has been triggered by the ever-increasing wireless connectivity and computational ability of recent vehicles. Many potential vehicular network applications have been proposed in different niches like information, safety, entertainment and traffic infrastructure management. These applications in these aforementioned applications require available wireless medium utilization of both new and existing wireless technologies. VANET comprises of two technologies known as WiMAX and Wi-Fi. The goal of this survey was to ascertain the best technology among the two technologies. In order to achieve this goal, a thorough investigation was carried out together with an evaluation on V2V2I VANET where Wi-Fi was used for amid vehicle (V2V) interaction and WiMAX used for vehicle to infrastructure (V2I) interaction. This survey begins with the VANET architecture, then discusses the characteristics and challenges of VANET, applications, before ending with a comparison of the two technologies that made of VANET, the experimental approach used, future perspectives, result and conclusion.

Keywords – vehicle to infrastructure, Wi-Fi, V2I, vehicle-to-vehicle, V2V, VANET, WiMAX.

1. Introduction

With the continuous development of wireless communication technology and vehicle industry VANET as of recent is one of the most research niches. VANET is a technology that makes use of motion vehicles as a node in a network for the creation of a mobile network. Vehicle safety measures provision is the goal of VANET, and this technology is created by the movement of vehicles and (RSUs), that is stationary roadside units furnished with wireless communication devices (short
range). There is both the vehicle to infrastructure and amid vehicle interaction in the networks [1-3]. What drives the (V2V) interaction is the Intelligent Transportation System development and deployment [4] which aims at improving the condition of traffic and reduction of an accident by offering drivers and users of vehicles information. Figure 1 shows main diagram of an Ad-hoc Network using Vehicles (VANETs).

![Figure 1: main diagram of an Ad-hoc Network using Vehicles (VANETs)](image)

There are many proposed applications for VANETs which are of two types namely the safety and non-safety [5]. The safety applications give out important and safety information from other vehicles sensor data or from stationary roadside units (RSUs) to avoid and report issues such as road conditions and maintenance information, immediate brake warning delivered from a preceding remote vehicle and accident announcement. Online connectivity, entertainment and general traffic management are some of the non-safety applications [7, 8] and they derive their data on-demand [6]. Video streaming, file sharing, electronic payments and audio are some of the examples. Figure 2 shows V2V2I system parts and operation.

![Figure 2: V2V2I system parts and operation](image)
The VANETs nodes have direction changes, sudden speed and high mobility attribute, unlike the nodes in MANETs leading to very swift changes in network topology [1, 9]. These factors gave rise to different challenges, like multipath fading, message routing techniques, degradation of the signal [10] and others. An essential factor is the putting of messages as a priority when one medium of the network is shared: these safety applications must have higher priority, however, there might have been an over flooding of non-safety applications in the network resulting to delay of safety and critical vehicle messages. One of the ways of overcoming these challenges is by separating the via a cross-layer architecture application [11]. Different safety applications can make use of the newly launched IEEE 802.11p, while Wi-Fi and WiMAX which are existing standards could be useful for different non-safety applications. Improved system performance and better usage of resources will be provided by this architecture [11]. The basic standard of wireless and local area cum short-range network protocol (Wi-Fi) is an IEEE 802.11 network. It operates on an unauthorized 2.4 GHz radio frequency providing over 120 Mbps (IEEE 802.11n) high data rates. WiMAX has its basis on the IEEE 802.16 standard.

2. VANETs Communication Architectures

Definition of Architecture was often regarded as a major issue by different organizations, like the International Standard Organization (ISO) and IEEE [14]. The task of creating 4 major standards (CALM, ARIB, C2C, and WAVE) began in parallel but lacking major coordination and collaboration. Many political forces, regional agencies, and car manufacturers support different standards.

2.1. CALM
ISO began its personal standard known as Calm which stands for (Communications, Air-interface, and Long and Medium range). This complex standard deal on uninterrupted node interaction or communication. CALM launched any interface that is available at the MAC layer before other standards. Nevertheless, there are many other MAC interfaces available to researchers.

2.2. C2C
The automobile industry in Europe supported a VANET standard under GEoNEt label via C2C-CC (Car-2-Car Communication Consortium). It aims at different active safety applications. It is not the same with the Internet architecture and it backs different open interfaces at the PHY layer and MAC layer.

2.3. WAVE
IEEE began its operation with WAVE label. WAVE (Wireless Access in Vehicular Environment) has its basis on the current internet model despite being a total protocol stack. There is no main large-scale implementation available apart from the small-scale projects and test laboratories [15]. Furthermore, only IEEE 802.11p MAC is permitted by WAVE for every communication that is regarded by many researchers as a bottleneck.

2.4. ARIB
ARIB gave definition to many VANET architectures and relied mainly on WAVE. ARIB-2001 which was the first ARIB standard uses one MAC layer at 700MHz band while ARIB-2004 uses a 5.8 GHz band. ARIB (The Association of Radio Industries and Businesses) just like WAVE has its focus on emergency VANET messages.

3. VANETs Characteristics and Challenges
VANET was initially considered as a sub-class of MANET, almost all studies and developments associated with MANET are put into practice use to VANET. Nevertheless, there were differences between the two classes of the network from subsequent progress. VANET model design for privacy, interaction, and security have no direct comparison with MANET. Many types of research were
carried out to make emphases to VANET issues in particular [12, 13]. This does not in any way solve all challenges; there are still many challenges where researches can carry out research to provide an optimum solution as a result of VANET not being implemented at a bigger scale.

3.1. Routing and Data Dissemination in VANETs
The following are the summary of routing and data dissemination in VANETs
- The state of real-life traffic is not taken into consideration before routes are determined by different protocols.
- Every realistic traffic maintenance and conditions can’t be met via the current and different VANET routing protocols.
- Utilization of routing protocols that are timely tolerant is prone to degradation in the course of disconnected scenarios.
- Under quick and inconsistent VANET topologies, all topology-based routes lack efficiency.
- Though proactive routing approaches offer low latency, there is an underutilization of network resources as a result of unused paths.
- Though reactive routing protocols offer better resource utilization, the major limitation is latency in route determination.
- Partitioning of network and accurate updating of location information result to network resource wastage.
- There may be incorrect emergency alerts caused by the inherent latency of GPS under high-speed movement [10].

Efficient routing has its focus on 3 major goals:
- Getting the best route from its wellspring to final abode efficiently
- New route updating at run time when a better one is available.
- Route maintenance especially when there is a route failure

The following are the 3 primary questions routing algorithms focus on when finding a route among 2 routes:
- What metrics or information ought to be shared for route determination?
- When the information and how the information is chosen ought to be shared inside the network?
- How to determine the route using the shared information?

3.2. VANETs Applications and Classification
The driving force of amid vehicle communication is roadway safety but bigger mobile applications and other bigger scale applications have also been presented by VANET. Different applications in transportation such as traffic monitoring and updates are expected from VANET. The major 3 VANET applications are safety, infotainment and traffic applications. Gathering and manipulation of data from roadside units and other vehicles are works of the traffic application, safety applications which depends on broadcast interaction are made up of low latencies that are transmitted across short distances and infotainment applications comprises of large payload information that needs high data rates.

3.3. Wireless Access Methods in VANETs/Access Technologies
This exploit commended a scheme that applies a joining together of Wi-Fi and WiMAX to consistently equip the mutual vehicle and V2I connectivity VANET. To make sure the reasonable evidence of vehicular network, a perfect information mix amid node extremities of a network expects, amongst other additional features, the node mobility comprehension under dissimilar surrounding conditions. The try out was made up of two vehicles that are related with a stationary place post and ad-hoc Wi-Fi association with a dedicated WiMAX association to a single-vehicle. Wi-Fi ad-hoc manner admitted the devices to pass on with one another without the exercise of AP (access point), and every device in orbit associate in a P2P manner. With the provision of extended coverage by WiMAX, it was decided and Wi-Fi as a result of being easy to access and similarity to the coming IEEE
802.11p measure gotten specifically for utilization in VANETs. There was a configuration of observational apparatus think over conditions release in an environment (urban) correctly.

3.4. Short/Medium Range Wireless Technologies--Wi-Fi Configuration (IEEE 802.11n)
Wi-Fi ad-hoc network was utilized in this setup due to the operational expectations of future vehicular networks in this fashion. There was direct communication among the devices in a p2p fashion. The primary limitation in ad-hoc mode is the depreciating performance of the network due to the growth of the number of devices. However, just 2 models are permitted to communicate in this experiment. Every wireless adapter in an ad-hoc network is meant to utilize identical channel number and SSID. Since Wi-Fi works on 2.4GHz unauthorized frequency band, the possibility of having interference from both Wi-Fi devices and other devices such as TV remote controls and Bluetooth is high. Identical 2.4GHz frequency band is used by TV remotes control and the Bluetooth. Comparing it to IEEE 802.11g, Wi-Fi (IEEE 802.11a) offers an inadequate performance. The transmission range, in general, was shorter. This led to both insufficient data successfully transferred and short contact time. This made Wi-Fi to be chosen for V2R communication architecture.

3.5. Wide/Long Range wireless technologies—WiMAX Configuration (IEEE 802.16d)
WiMAX was launched by the WiMAX Forum with a target of conceiving a system for mobile and fixed broadband combination wireless access. The WiMAX Forum currently comprises of fixed system profile (IEEE 802.16d-2004) and mobile system profile (IEEE 802.16e-2005). Breeze Max selfinstall (Si) 1000 CPE and Alvarion BreezeMax TDD Micro (BS) were utilized for the WiMAX link. The (Si) CPE was constructed to be used indoor. It makes use of the Intel PRO or Wireless 5116 broadband interface chip. It provides full 360° coverage due to its fast bi-directional switching matrix. Utilization of different or same antennas to sending and receiving information was made possible by the bi-directional (double) switching matrix. The Si CPE was linked to the personal computer via the 10/100 base T port. The Si supports 64QAM, 16QAM, BPSK, 1/2, 2/3, ¾ coding modulation techniques and QPSK. To control the coding schemes and modulation, uplink and downlink quality are monitored regularly. The BS chooses a modulation technique of the aforementioned coding by making use of multirate algorithm link quality information that includes Signal to Noise Ratio, Burst Error Rate and multipath gotten from the SU. Both the Base Station (BS) and SU work with the IEEE 802.16d standard that operates at 2.5GHz frequency band and utilizes time division doubling with a 5MHz channel bandwidth.

4. Comparisons of Wi-Fi and WiMAX
• Wi-Fi connection is slower than WiMAX
• Both technologies have reliable and simple QoS.
• The distance and speed of a network are the main difference between the 2 technologies.
• While Wi-Fi has a limited access point, WiMAX has no access point.
• WiMAX has a medium band with unlike Wi-Fi that has less bandwidth.

| Standard       | WiMAX                       | Wi-Fi                        |
|----------------|-----------------------------|------------------------------|
| Family         | 802.16                      | 802.11                       |
| Application (primary) | Broadband wireless access        | Wireless LAN                  |
| Channel Bandwidth | 1.25 M to 20 MHz (Adjustable) | 20 MHz                       |
| Radio Technology | OFDM (256-channels)         | OFDM (64-channels)           |
| Uplink (Mbit/s) | 56 in 20 MHz bandwidth      | 300 in utilizing 4x4 configuration in bandwidth of 20MHz |
| Access Protocol | Request/Grant | CSMA/CA |
|-----------------|---------------|---------|
| Frequency Band  | 2 G to 11 GHz (Licensed and Unlicensed) | 2.4 GHz ISM (g) 5 GHz U-NII (a) |
| Downlink        | 128 in 20 MHz bandwidth | 600 in utilizing 4x4 configuration in 40MHz bandwidth |
| Basis use       | Used for mobile Internet | Used for mobile internet |

5. Experimental Setup and Approach

An investigation was done on the combined performance of WiMAX network protocol and Wi-Fi wireless protocol to give mutual vehicle and vehicle to infrastructure connectivity respectively in VANET. The experiment was made up of two connected vehicles. Both vehicles are connected with a stationary base station and ad-hoc Wi-Fi. A dedicated WiMAX was also connected to one vehicle. It was well-designed to reflect correctly the resent conditions in an urban environment. This survey has its focus on scenarios that support the movement of vehicles in a particular direction and in opposite directions. Stellenbosch University campus was the place where the experiments were done on the on 2 different routes inside WiMAX Base Station range. 60km/h is the authorized speed limit on these 2 routes. The first route is not far from the BS in line Of Sight of the WiMAX Base Station range while the second route is of farther from the WiMAX network Base Station range in the city centre. This city centre represents non-line of sight. Early tests were carried out to ascertain the individual evaluation of Wi-Fi and WiMAX since both technologies were involved. Tests on the combined technologies were done later.

- For the test done only on Wi-Fi wireless network communications
  - Vehicles moving in a single and opposite directions on V2V following, V2V crossing and V2I were carried out.
- For the test done only on WiMAX network communication
  - The vehicle that was enabled by the WiMAX network was moved in both routes.
- For the complete test utilizing both wireless protocols communications
  - Two tests on both direction and opposite direction was carried out on both routes. Also, another test was carried out when the 2 vehicles were on the same direction (following) for a distance of 50 km with speeds close 120 km/h on a route (highway). In this test, the separation range was also kept under 300 meters. For this particular test, the WiMAX connection, unlike the active Wi-Fi connection. To add to the performance results (quantitative link), both the amid vehicle and V2I configuration was equally utilized in the qualitative evaluation of the link using audio and video streaming amid the vehicles first, it was seconded from the BS to the WiMAX enabled vehicle and finally from the Base Station via the vehicle enabled by WiMAX to others. Each vehicle was furnished with a personal computer together with an external Wi-Fi adapter. These external adapters were installed at the exterior of the vehicles to offer to enhance coverage and LOS. WiMAX Base Station was installed on a tall building. The personal computer used composed of GPS dongle for monitoring the speed and position of the vehicles. The following were recorded during the experiment:
  - Relative speed
  - Both technologies signal strength
  - Both technologies modulation type
  - The separation amid the vehicles
  - The separation from the Base Station
  - The data transferred
  - Jitter
  - The contact time from the first to the final packet received

6. Future Perspectives in Vehicular Networks
This survey shows the better scenario in VANAT where there are 2 communicating nodes at the absence of users collision and contention. Knowing the evaluation of where there are two nodes trying to communicate would be beneficial and as such would require future investigation under denser scenarios to know the evaluation of multiple vehicles sharing one medium. The utilization of both wireless technologies needs further experiment to deduce additional and real-time behavioural communication in VANETs. Also, there would be a need for a further experiment to know the implications in the use of many non-wire technologies and how to manage their coexistence.

7. Result and Conclusion
The execution of Wi-Fi compared with the execution or performance of WiMAX was greatly suitable and recommendable. The challenges encountered in Wi-Fi are solved using WiMAX. The major challenge facing Wi-Fi is the restricted area which is not so in WiMAX that has no area restriction. Both network technologies are trusted and reliable. Infotainment diligences feasibility in VANETs calculates not only on the features of the vehicular network but also the intermediate communication or interaction in conditions of its operation under such networks. The operation of Wi-Fi as a provider of amid vehicle communication and functioning of WiMAX as a provider of a vehicle to infrastructure communication in VANETs was evaluated. Finally, scenarios with tangency orbits, illustration vehicle accelerates, tangency lengths and points of urbanization were directed.

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