ISSN:0975-9646

Akshata Gandhi et al, / (IJCSIT) International Journal of Computer Science and Information Technologies, Vol. 3 (4) , 2012,4823-4828

Role of Wireless Technology for Vehicular Network

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***Abstract*—All automobile manufacturers continue to incorporate more and more technological features into their vehicles. One of the features is wireless access. A Vehicular Ad-Hoc Network or VANET is a technology that uses moving vehicles as nodes in a network to create a mobile network. VANET turns every participating vehicle into a wireless router or node. Some measurement studies have previously been undertaken to understand feasibility of using Wi-Fi for VANET communication. Recently WiMAX is emerging as one of possible candidates for next generation mobile networks.**

Intelligent Transportation System (ITS) converges remote sensing and communication technologies to improve safety and to make journey enjoyable. This is now part of national strategy, for improving security, safety, efficiency and comfort, of every nation. Mobile WiMax is a suitable wireless technology for networked vehicular applications because of its mobility support at vehicular speeds and its inherent wide coverage, which minimizes rate of handover and thus data loss due to disrupted communication. Apart from vehicular mobility, terrain over which network is deployed will also impact network due to its effects on wireless signal propagation. In this paper, we analyse wireless technologies such as Wi-Fi, WiMAX, and DSRC. We will also see current scenario and problem definition in VANET.

***Keywords*— Mobile WiMAX, WI-Fi, VANET, ITS, DSRC, V2V, V2I**

I. INTRODUCTION

Vehicular wireless communications and vehicular ad hoc networks are nowadays widely identified enablers for improving traffic safety and efficiency. A vehicular ad-hoc network (VANET) is a communication technology for vehicle to vehicle (V2V) which is one of the mobile ad-hoc network (MANET) applications, vehicular to infrastructure (V2I) and vehicle to roadside (V2R). Apart from safety measures, VANET also provides value added services like email, audio/video sharing etc, [11]. In order to support mobility, a network infrastructure will need to be designed and implemented. This infrastructure will need to provide reliable network access to objects travelling at high speeds. Access will need to be similar to what a person currently has at home, if not better. Currently, there are emerging next-generation wireless technologies that are intended specifically for mobile data access, targeting wireless access in mobile environments such as a vehicle.

Large number of suggestions for vehicle-to-vehicle (V2I) and vehicle-to-infrastructure (V2V) communication have been presented. Communication between cars will be arranged in an ad hoc manner, supported by wireless base station connection to backbone network whenever possible. The platform consists of a specific set of services (e.g., local road weather service and incident warning service), but a variety of services can be integrated to this kind of a system. The ultimate goal was to enhance traffic safety and smoothness, but also to generate a completely new communication entity, allowing new types of applications, services, and business opportunities.

Lots of potential applications of VANET:

- Safety services: Emergency brake light, collision warning etc
- Enhanced road services: Toll services, parking space locator, map updates, etc
- Other entertainment services: Internet surfing, video on demand, on-gaming, vehicular social networks, etc.
- Data Processing applications and Systems: Traffic simulation System, Traffic status and incidents Reporting Systems etc.[1]

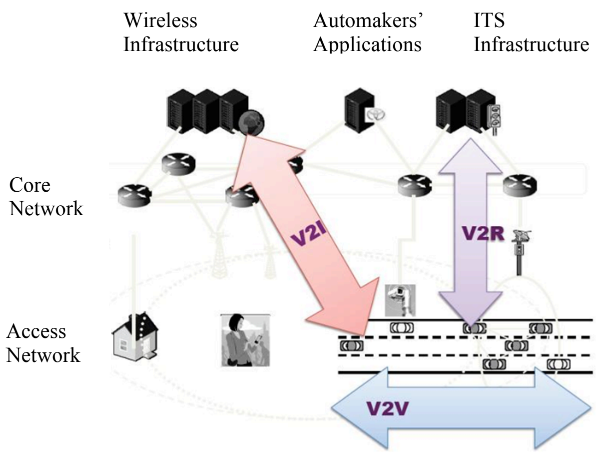

Figure 1: Communication Types for VANET

Several manufacturers have already incorporated Bluetooth into their cars to create a personal area network within the car. Saab introduced its 2003 9-3 with Bluetooth and momentum is continued with 2004 models from Acura, Audi, Lexus, Lincoln, Mayback, and Toyota, to name a few. Lincoln already has a model with Wi-Fi technology. Toyota is in process of rolling out an on-board GBOOK terminal, which will be an automotive PDA featuring a Data Communications Module and a Secure Digital card enabling customers to take advantage of latest network services as easily as they would operate a car radio [14]. Fiat Auto and Microsoft announced a long-term strategic automotive partnership to develop innovative telemetric and solutions for motorists [13]. Microsoft's Automotive Business Unit already has a Windows Automotive platform that includes Bluetooth, Wi-Fi and 802.1x wireless technologies. Analysts are projecting that automobile manufacturers will continue to incorporate wireless features into their automobiles [16]. But current wireless infrastructures cannot furnish necessary bandwidth and capacity needed to provide desired services to users travelling at high speeds. Therefore, a wireless infrastructure, aimed specifically toward providing Internet access at high speeds, will need to be put in place to support the 25 million vehicles estimated to have wireless access by 2008[15].

II. CURRENT SCENARIO OF VEHICLE NETWORKING

Currently, networks (both wired and static) have only been available in hot-spots, commercial buildings, or homes. Consumers are beginning to demand access anytime from anywhere including an automobile. They want wireless Internet access whether shopping at the mall, waiting at airport, walking around town, or driving on highway. They want to have ability to surf the Web, download files, and have real-time video conference calls and other tasks, through a wireless communication connection to Internet with same data rates as their desktop.

Field tests consisted of two scenarios, base station-to-vehicle and V2V, as presented in Fig. 2. The base station was located in an open area, without any physical obstacles nearby between vehicle and base station (at least not in close range, i.e., less than 500 meters). We started measurements varying delay and data packet size, but soon concentrated to repeating scenarios as shown in Figure 2. With these basic communication scenarios we aimed to test basic operability of WiMAX in a vehicular networking environment [2].

Scenario 1: Vehicle to Vehicle communication approach is most suited for short range vehicular networks. It is fast and Reliable and provides real time safety. It does not need any roadside Infrastructure. V2V does not have the problem of Vehicle Shadowing in which a smaller vehicle is shadowed by a larger vehicle preventing it to communicate with the Roadside infrastructure. We had two vehicles passing by each other with pre-defined speeds; one of vehicles is sending data in a pre-defined pattern and other one capturing successfully received data. The same variations of packet size were used here, but the delay was kept constant as communication window during bypass was expected to be too small for a large delay.

Scenario 2: Vehicle to Infrastructure provides solution to longer-range vehicular networks. It makes use of pre-existing network infrastructure such as wireless access points (Road-Side Units, RSUs). Communications between vehicles and RSUs are supported by Vehicle-to-Infrastructure (V2I) protocol and Vehicle-to-Roadside (V2R) protocol [11]. The Roadside infrastructure involves additional installation costs. We emulated typical Car link platform operation of a vehicle passing by base station and exchanging platform data. For this scene vehicle drove back and forth through location of base station with a pre-defined speed, and during this drive we captured instances of successful data transmission delivered in a predefined pattern from base station to vehicle. We tried to deliver as much data as possible, but especially chose two packet sizes to transmit (in separate measurements) in order to find optimal delivery type. A 315 byte packet is standard size of a weather station report, representing a small packet size in our measurements. A large packet size in our measurements is 1202 bytes, simply constructed from four small packets (with just one packet header). For large packets we also tried to find effect of packet transmission interval to delivery rate by using two clearly different delays between consecutive packets, 1 ms and 10 ms, respectively. Obviously packet sizes used as well as transmission intervals are not necessary optimal ones, but rather pointing to parameter space where optimal values are likely to be found. The V2I infrastructure needs to leverage on its large area coverage and needs more feature enhancements for Vehicle Applications.

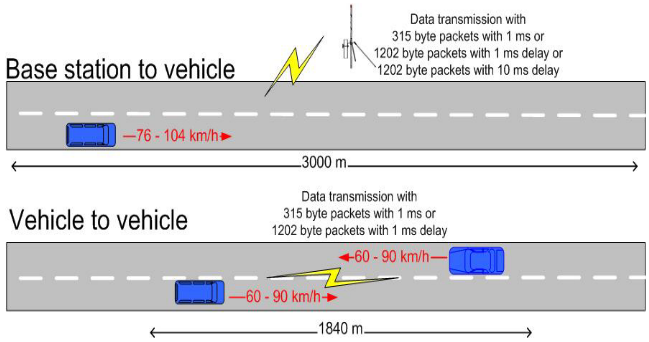

Figure 2: Field measurement scenarios

I. PROBLEM DEFINITION

Design and simulate an application specific vertical handover among WiMAX, UMTS and WLAN for ITS using Analytic Hierarchy Process (AHP). We are taking following criteria into consideration while selecting technology on entering a cell having two or more of above radio access networks [3]:

Triggering factor	Received Signal Strength (RSS) (Availability of the network)
Critical factor	Terminal Mobility (Speed of the vehicle)
Influencing factors	Bandwidth (depends on Application type), Initial Delay, Network Traffic Load, Usage cost

Suppose user is moving from a cell to another as shown in Figure 3. In typical highway traffic, we have considered five different situations. At position A, the vehicle has passed toll plaza and is about to enter in a city.

Thus all three radio networks are available here. Point B is almost similar to point A; here vehicle is in a suburban area. Point-C is far from city and only UMTS network is available here.

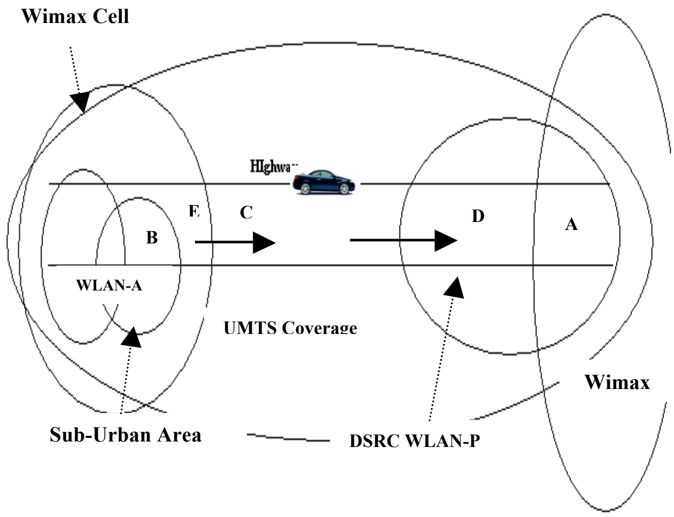

Figure 3: A Typical Radio Network Availability Scenario for ITS

Point-D is near to toll plaza, and UMTS along with dedicated short range communication (DSRC) network is available here. Currently, IEEE standard proposed for DSRC, known as 802.11p, is based upon IEEE 802.11a standard. The physical Layer of 02.11p standard is same as physical Layer of 802.11a standard, except for used sample rate. The main application of 802.11p is V2V communication. V2V is also a synonym for DSRC. DSRC is already in use in USA, Europe and Japan for electronic toll collection [20]. Point- E indicates suburban area where WLAN network is not available and vehicle is in edge of WiMAX coverage area. Handover needs to take place when either RSS is critical or QoS is poor for current radio access network. Applications taken into consideration are Conversational, video streaming and normal file transfer (data streaming). Each of these applications requires a different bandwidth. All three technologies do not support these applications with equal QoS. Each wireless technology has a limit on maximum amount of mobility it can support. As we are considering a transportation system, speed of vehicle (mobility) is an important factor that is to be taken into consideration. WiMAX supports highest mobility among three and WLAN has lowest support for mobility and least coverage area [20].

Another parameter taken into consideration is Initial delay, which is setup time for a connection. Initial delay is more in some systems compared to others. According to Fiedler et al., delay could be up to seven seconds for UMTS. WLAN connectivity, on other hand, is perceived as responding instantaneously. WiMAX response could be faster than UMTS but slower than WLAN [3].

III. INTELLIGENT TRANSPORTATION SYSTEM (ITS)

Intelligent Transportation System (ITS) converges remote sensing and communication technologies to improve safety and to make journey enjoyable. Wireless communication system is one important part of city for its data collecting and transferring function. The ITS network uses a multitude of technologies including fiber, point-to-point microwave as well as WiMAX. ITS applications can be broadly classified in two categories [7]:

- Safety applications: Automatic cruise control (ACC), Driver assistance systems (DAS) and Collision avoidance and warning systems (CAWAS) are some examples of safety application.
- Non safety application: Internet access from car, vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) communication, satellite television from car, radio taxi, and automatic toll collection are categorized as non-safety applications.

Some of the benefits of the ITS network includes:

- Traffic Management
- Dynamic Messaging Signs
- Solar-Powered Traffic Detection Radar Sites
- Seamless Connectivity to Traffic Management Centers (TMCs)
- Wireless Remote Management

Intelligent Transportation System (ITS) needs an "always best connected (ABC)" communication to ensure vehicular safety. Intelligent Transportation System (ITS) is an application of WiMAX which is characterized by heterogeneous radio access networks.

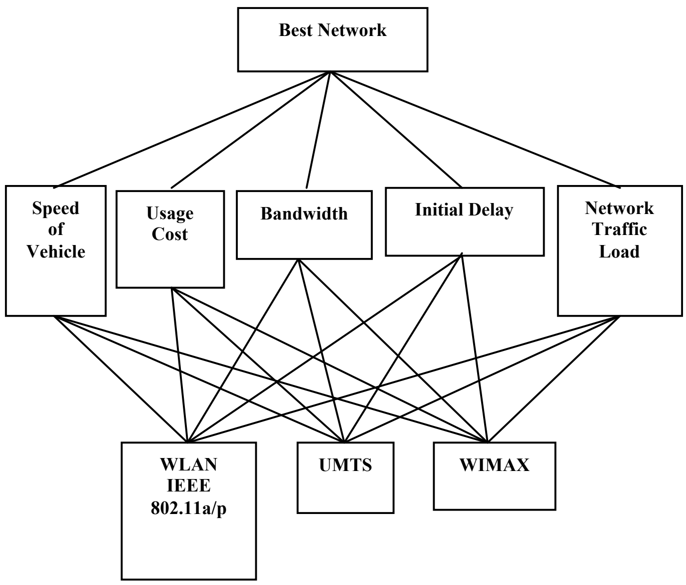

Figure 4: Hierarchy of criteria for "best network" selection.

Figure4 presents a hierarchy of criteria with goal of "best network" selection for seamless vehicular communication. To be able to reach this goal four criteria have been defined: usage cost, speed of vehicle (mobility), type of application (bandwidth), network traffic load and initial delay to setup communication link. Received signal strength (RSS) will act as a triggering factor, i.e., a network will be considered as an alternative if and only if RSS of network is above threshold at that instant.

There are two main categories of communication traffic, i.e., conversational and streaming (data and video). Depends upon these there is following criteria for choosing one network: Mobility (speed of vehicle), bandwidth, network traffic load, delay and usage cost.

It is evident from priority vector that vehicular speed is critical factor for handover in a vehicular communication system. Bandwidth of a particular network indicates its ability to support different types of applications. For example, voice communication needs low bandwidth but video transmission requires very high bandwidth. Traffic load is also an important factor as QoS of a network depends on user accommodation capability. Since safety applications are associated with vehicular communication hence initial delay for connection establishment is expected to be less. If QoS is equivalent for two networks then user will always opt for a network which offers low cost of service. Thus usage cost is another influencing factor for vertical handover. The priority vector gives a quantitative representation of relative importance of these influencing factors.

IV. VANET USING MOBILE WIMAX

A. *Communication Requirements for VANET*

Based on services, Wireless network for VANET should support point-to-multipoint and point-to-point transmission mode. Information can be transmitted either event-driven or periodical. If information is periodically generated, interval time should be defined. Wireless communication technology should be satisfied with maximum duration of time to transmit as well as maximum distance between source and destination. The maximum required range of communication is explained to 1Km for approaching emergency vehicle warning [12]. The minimum update rate is every second for approaching emergency vehicle warning and allowable latency is less than one second.

The ITS communication architecture for VANET is described and compared access technologies. WiMAX is most appropriate access technology for VANET. They review access technologies which divided into three categories [4]:

- Short range/ad-hoc: Technologies for short and ad-hoc are including CEN DSRC at 5.8GHz based on CEN EN 12253-2004, European 5.9GHz ITS based on IEEE 802.11p, wireless local area network specified at 5GHz by IEEE 802.11p, infrared based on ISO21214.
- Cellular: The cellular technologies are encompassed WiFi, also known as wireless fidelity, at 2.4GHz based on IEEE 802.11a/g, WiMAX at 2.3GHz, 2.5GHz and 3.5GHz based on IEEE 802.16 and IEEE 802.16e, GSM/GPRS at 800MHz and 1.8GHz based on GSM standard, UMTS at 800MHz and 2GHz based on 3GPP standard. Almost all of applications are based on V2I, therefore cellular technologies can be considered more important than ad-hoc technologies. Moreover, cellular technologies are technically verified whereas ad-hoc technologies are still required research and development
- Digital broadcast

B. *Wireless technologies analysis for VANET*

Wi-Fi: WLAN is based on the IEEE 802.11 standard family. The most common current versions are 802.11b and 802.11g standards operating in 2.4 GHz bandwidth and capable of up to 54 Mbps (.11g) or 11 Mbps (.11b) data speeds, respectively. Recently also some devices supporting forthcoming (.11n) standard have been published, expected to be able to provide up to hundreds of Mbps data speeds. However as this standard is not yet approved compatibility of different devices between each other and with final standard remains as an open issue [2].

WiMAX: The IEEE 802.16 family of standards specifies air interface for both fixed and mobile broadband wireless access (BWA) systems supporting multimedia services. WiMAX system is based on these technologies. IEEE 802.16-2004 for fixed and IEEE 802.16e for mobile access, respectively, are the IEEE standards which define current structures of WiMAX system. WiMAX has licensed worldwide spectrum allocations in 2.3 GHz, 2.5 GHz, 3.3 GHz and 3.5 GHz frequency bands and is capable of up to 31.68 Mbps data rates with a single antenna system and up to 63.36 Mbps with a multiple antenna system. The WiMAX is capable of supporting fast moving users in a mesh network structure. Systems with users moving at speeds up to 60 km/h have been reported. However just recently there has been lot of discussion whether WiMAX will ever achieve commercial success, due to long delivery delays and problems in large scale WiMAX network deployment projects (e.g. Sprint nationwide WiMAX network in U.S.A.) [2]. Highway monitor network system based on WiMAX technology contributes to dealing with accident and improving road managing level of highway, which is helpful to form high efficient emergency handling system.

DSRC: The IEEE standardization activity for car-to-car communication environment is named as WAVE (IEEE 802.11p) [5]. The underlying technology in this standardization work is called Dedicated Short-Range Communication (DSRC) presented in IEEE 1609 standard [6], which is essentially IEEE 802.11a standard adjusted for low overhead operations. Primary purpose of DSRC is to enhance public safety applications, to save lives and to improve traffic flow by V2V and infrastructure-to-vehicle communications. Ultimate goal in design of IEEE 802.11p has been flat distributed communication, achieved by avoiding channel scanning, association process and authentication process prior to data exchange. In U.S. a 75 MHz channel has been allocated for DSRC in 5.9 GHz spectrum. During autumn of 2008, a 30 MHz channel has been allocated for vehicular communication in Europe, in the 5.875-5.905 GHz bandwidth.

Some prior studies used IEEE 802.11radio technology to evaluate feasibility of vehicular network in a real world scenario for both V2I and V2V communication. For example, Ott [9] performed measurements from cars running at high speeds (from 80km/h to 180km/h) on an autobahn in German. Their results showed that distance between vehicles is main factor that affects connectivity of V2I communication. Wellens et al. [10] measured good put, frame error rate of a vehicular network under different conditions such as different speed, communication distances, data rates, etc. Their results showed speed is a negligent factor when using Wi-Fi for short distance V2I communication. Jerbi et al. [8] measured performance of multi-hop communication in a vehicular network using Wi-Fi in three different scenarios: V2I, V2V and Hybrid. Their results again indicated communication range is major factor that affects V2I communication.

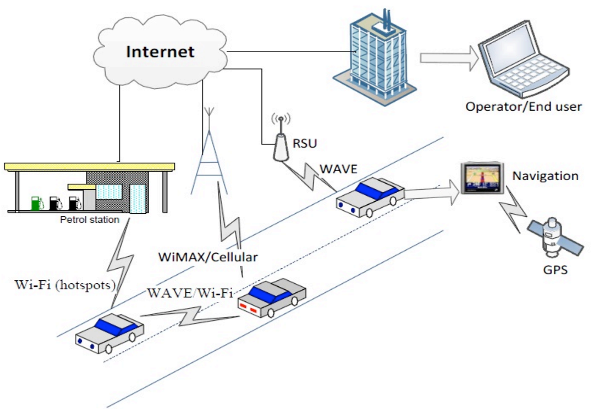

Figure 5: Illustration of vehicle Network

Although fundamental technology is same, biggest difference between Wi-Fi and WiMAX is in coverage area. This translates into more base stations required for Wi-Fi, which means deployment of vehicular network infrastructure would be more costly. Wi-Fi was really optimized for indoor use and for short ranges. Wi-Fi may be a good solution for toll collection, drive-through windows, etc., where you can have a fixed receiver and transmitter is known to be a given distance away. WiMAX was optimized for use outdoors. Wi-Fi technology was really actually designed and optimized for Local Area Networks (LAN), whereas WiMAX was designed and optimized for Metropolitan Area Networks (MAN). Wi-Fi base stations cannot support as many users as WiMAX base stations. Wi-Fi was only designed to support one to ten users per base station with a fixed channel size of 20 MHz per base station. WiMAX was designed to support one to no more than five hundred users per base station, each with a variable channel size from 1.5 MHz to 20 MHz [17]. There are also frequency band differences. WiMAX uses licensed spectrum whereas Wi-Fi uses unlicensed spectrum. WiMAX uses one of unlicensed frequencies, but also supports two other frequencies that are licensed. What that means is that you can turn up output power and broadcast longer distances. This also makes WiMAX a better choice because Wi-Fi only works in unlicensed spectrum and only has a 20 MHz channel bandwidth. That means it's contention-based, so if one person is on that channel another person getting on would have to share same capacity. Therefore, it's much more limited in its ability for going long range. As you get more users, bandwidth is divided up among users. Also, WiMAX was designed to be a carrier-grade technology, which requires a higher level of reliability and quality of service than is now available in typical Wi-Fi implementations.

C. V2I Architecture with Mobile WiMAX

Architecture of VANET based on WiMAX which consists of several logical network entities including subscriber station (SS) or mobile station (MS), access service network (ASN) and connectivity service network (CSN) [18]-[19] as shown in figure 6. The SS/MS is user equipment set providing wireless connectivity. The SS is for fixed device terminal and it is not required to support handover capability. The MS providing handover function is installed or embedded in car for VANET and it should support handover.

ANS is a set of network functions to provide wireless connection and WiMAX system profile. These functions are including media access control for MS, transfer of authentication, authorization and accounting (AAA) messages by RADIUS or diameter, preferred network discovery and selection, radio resource management and Internet protocol (IP) connectivity. ASN is composed of BS and ASN gateway which connects several BSs based on cell planning. Local server is required for VANET application. The local server processes collected information from the MSs in vehicles and sends warning messages to MSs. The messages types depend on the application such as warning for dangerous road features, danger of collisions, accident information and so on.

CSN is a set of network functions that provide IP connectivity service to MS. CSN comprise network elements such as router, gateway for interworking and various kinds of servers. These servers are including DHCP for IP address allocation, AAA proxy/server, user database, home agent for mobility management, central server for VANET application and so on. [4]

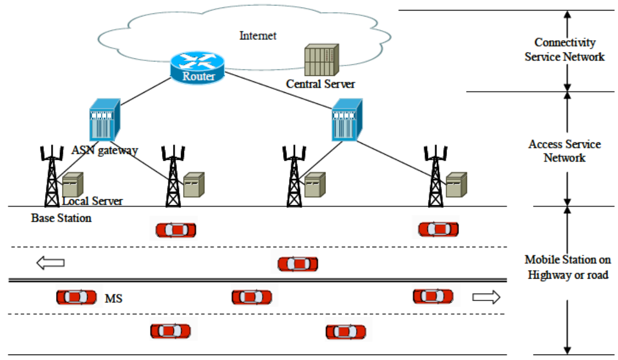

Figure 6: VANET architecture with mobile WiMAX

V. CONCLUSION

The VANET contributes to preventing chain collision from unexpected vehicular conditions or falling by delivering the information on driving information and road conditions. It can support improved traffic control by monitoring road condition and traffic information. Therefore, it is important to provide vehicle information, road condition, and traffic information for the application. An efficient assessment system is essential for appropriate network selection. We have considered these radio access networks (WLAN, UMTS, WiMAX), which is the international standard (ISO 21217) for ITS, supports all of them.

Mobile WiMAX is competitive to the wireless access for vehicular environments (WAVE) for communication technology. We describe VANET network architecture and requirement to use mobile WiMAX network. WiMAX is better than Wi-Fi and DSRC for VANET infrastructure. First, the WiMAX can provide more application than Wi-Fi and DSRC. Second, Though DSRC has been performed R&D in ITS for decades, a limited applications are possible now. The WiMAX can provide Internet service and ITS application with little efforts. Third, the WiMAX can support multimedia application for large scale; however the

Wi-Fi and DSRC can possible limited applications due to its radio coverage. Vehicle track guarding against theft based on WiMAX monitor system can provide secure services, impelling relevant increment services development.

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