

Vehicular Networks: embracing wireless heterogeneous communications through Vertical Handover

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Abstract— By taking advantage of the ever growing deployment of wireless networks, the automotive industry is increasingly enabling vehicles to communicate with one another and with the infrastructure, with benefits to information delivery and safety on the road. Vertical Handovers can be used to ensure that the Quality of Service demanded by applications (*e.g.*, throughput, latency) is met while the vehicle is changing its position. In this paper we present a Vertical Handover Decision Algorithm empowered by the IEEE 802.21 standard and its services. Our proposed algorithm uses the vehicle's on-board unit features and considers the geolocation, the car navigation and a realistic propagation model for heterogeneous underlying networks such as Wi-Fi, WiMAX, and UMTS. Our results demonstrate, through a case of study, that QoS can be guaranteed when location and networking parameters are jointly considered when performing vertical handover.

Keywords— Vehicular networks, heterogeneous wireless networks, geolocation, IEEE 802.21, Wi-Fi, WiMAX, UMTS, ns-2, GPS.

I. INTRODUCTION

NOWADAYS, cars are being empowered by advanced On-Board Units (OBUs), which are enhanced by features such as faster processors, high definition displays, and multiple wireless networking technologies, offering full connectivity inside and outside of the car in order to deliver and to access different content (*e.g.*, safety messages, advertisements, or a movie) while the car is moving. Thus, these units offer not only voice services, but also infotainment.

Due to wireless impairments and to mobility issues, the Quality of Service (QoS) can be affected or the link may be lost while crossing different coverage areas, whether the areas are covered by the same technology or not. To be able to switch from one network technology to another without affecting the QoS (*e.g.*, bandwidth, packet latency), Vertical Handover (VHO) techniques are required. The IEEE 802.21 protocol [1] has been developed to improve VHO processes, by offering a homogeneous middleware that can be accessed by applications to communicate with heterogeneous network interfaces, contributing to simplify the complexity of the multi-interface management. Through this middleware, different services can be accessed in order to obtain

context information (such as Point of Attachment (PoA) information and geolocation, local information, network information) as well as to interact and perform different actions on the interfaces, based on such information.

Concerning the Vehicular Networks (VNs) context and VHO processes involved, many mobility and location issues must be considered. The intrinsic characteristics of the VNs, such as dynamism, speed, and intensely changing contexts, present a challenge for VHO. Other features of the VNs, such as availability of geolocation through the Global Positioning System (GPS), and the lack of power restrictions due to the continuous energy source, allow the devices to improve the gathering of context information in order to perform an accurate decision on choosing the most suitable candidate network to hand over to, thus improving the VHO process.

In this work, we present a Vertical Handover Decision Algorithm (VHDA) which combines GPS information (both geolocation and navigation), underlying network information (based on realistic propagation models), as well as network architecture information, in order to optimize the network selection process, a critical element of VHO.

II. RELATED WORK

One of the first approaches using GPS systems for improving handover was presented by Dutta *et al.* in [2]; the authors present a methodology related to GPS-IP discovery for intra-technology handovers considering layer 2 detection, IP address assignment, and duplicate address detection. Yliantila *et al.* [3] present work based on GPS support for inter-technology handovers considering Wireless Fidelity (Wi-Fi) and Universal Mobile Telecommunications System (UMTS) technologies. The authors propose a location-aware architecture to perform vertical handovers based on location management and resource allocation taking into account the mobility in and out of the cells.

A method to enhance link and network layers handover by predicting the future position via GPS was presented by Montavont *et al.* in [4]. The authors combine Wi-Fi and GPS information in order to perform the network selection process. Concerning Worldwide interoperability for Microwave Access (WiMAX) technologies, Hsiao *et al.* in [5], make use of a combination of GPS information and WiMAX interface status information to avoid scanning the

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channel and to pre-connect to the PoA, hoping to provide stable WiMAX service.

III. PROPOSED VHDA

The proposed algorithm takes advantage of the car's features, such as powerful OBUs, GPS (geolocation and navigation information), different networking interfaces, and context information provided by the IEEE 802.21 standard. However, to design an accurate VHDA able to perform the handoff not only considering the most adequate candidate network to switch to, but also considering the time to leave the current PoA and join the target one, we must estimate the packet loss conditions associated with the different networks at different distances between vehicle and PoA. To obtain a valid network conditions model we have performed several measurements within the Polytechnic University of Valencia campus and the University of Murcia campus, observing real Wi-Fi and WiMAX behavior [6], respectively.

The proposed algorithm is composed of three tasks: Networking, Neighborhooding, and Decision-making tasks. Figure 1 presents the flow diagram of the algorithm.

The wireless network sensing process is performed in the networking task. It periodically sends and receives information about the network status (*e.g.*, Router Advertisement (RA) and Router Solicitation (RS)). The IEEE 802.21 services, *i.e.*, Media Independent Event Service (MIES) and Media Independent Command Service (MICS), check the link status and the reports received, notifying the upper layers for taking further actions.

Regarding to the Neighborhooding task, there are two data storage elements that collect the surrounding information related to the Current Neighborhood and the Future Neighborhood. Both storage elements are periodically filled-in with information about the current and future PoAs available, respectively. By consulting the GPS module, the current and future geolocation within the map and route (navigation information) is stored and used in order to access the PoA information database, powered and made available by the Media Independent Information Service (MIIS) of IEEE 802.21. A list of current and future available PoAs is retrieved and locally stored at the OBU to be used by the decision-making tasks. Based on the MIIS information, this task also calculates the useful coverage time under each PoA coverage by combining the GPS information about the route on the map and the MIIS information. The useful coverage time is affected by different issues, such as how tangentially the route crosses the coverage area, the times for reaching/leaving a coverage area, the existence of overlapping coverage areas along the path, and the cell coverage at a given target QoS, which we refer to as the 'QoS border' considered by the decision-making task, as shown in Figure 2.

Finally, the selection of the target network is made by the decision-making task. This process is in

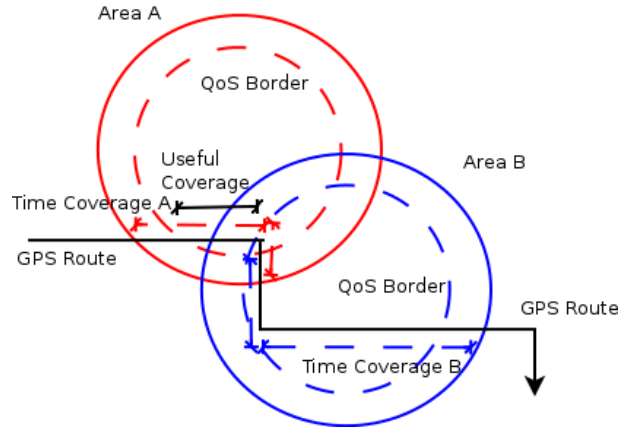


Fig. 2. Useful coverage and QoS example.

charge of evaluating all the gathered information and, based on a Multiple Criteria Decision-Making (MCDM)-based evaluation [7], the candidate PoA which best fits the application's requirements is chosen. The main decision logic of our proposed algorithm, whose aim is to guarantee the QoS, considers the cell coverage time and guaranteed QoS border of the cell, and allows handovers to take place only when there is alternative useful coverage available, considering also the distance to the QoS cell border of the PoA involved in the decision process. As shown in Figure 2, when a vehicle arrives to the coverage area A, the wireless network interface triggers a Link Detected event, starting the VHDA process. If we based the decision on the Time Coverage A, considering neither the immediate future nor the QoS border, we could make a mistaken decision, since the vehicle will soon leave the coverage area A to join the coverage area B, and so the VHO would be worthless.

To complete the whole VHO process, different notification-update processes are triggered at the server to handle the mobility issues by using Mobility support for Internet Protocol v.6 (MIPv6), OBU's wireless interfaces, and networking elements, thereby redirecting the flows and keeping the connection alive.

IV. SIMULATION SCENARIO

For our simulations, we have used a well-known simulator within the wireless networks area: the Network Simulator (ns-2) [8]. Moreover, we have used the *NIST mobility package for ns-2* [9], in conjunction with EURANE [10], taking advantage of the many capabilities and features offered to simulate Wi-Fi, WiMAX, and UMTS technologies, and to perform VHO among them. Furthermore, the NIST add-on also enables the MIES and MICS services of the IEEE 802.21 standard to interact with heterogeneous network interfaces under homogeneous standard primitives. Concerning the Media Independent Information Service (MIIS), we have used our version previously developed in [11], as well as the Global Positioning System (GPS) add-on module for the ns-2 presented in [6] for geolocation capabilities.

In our simulation, we have modelled vehicles mov-

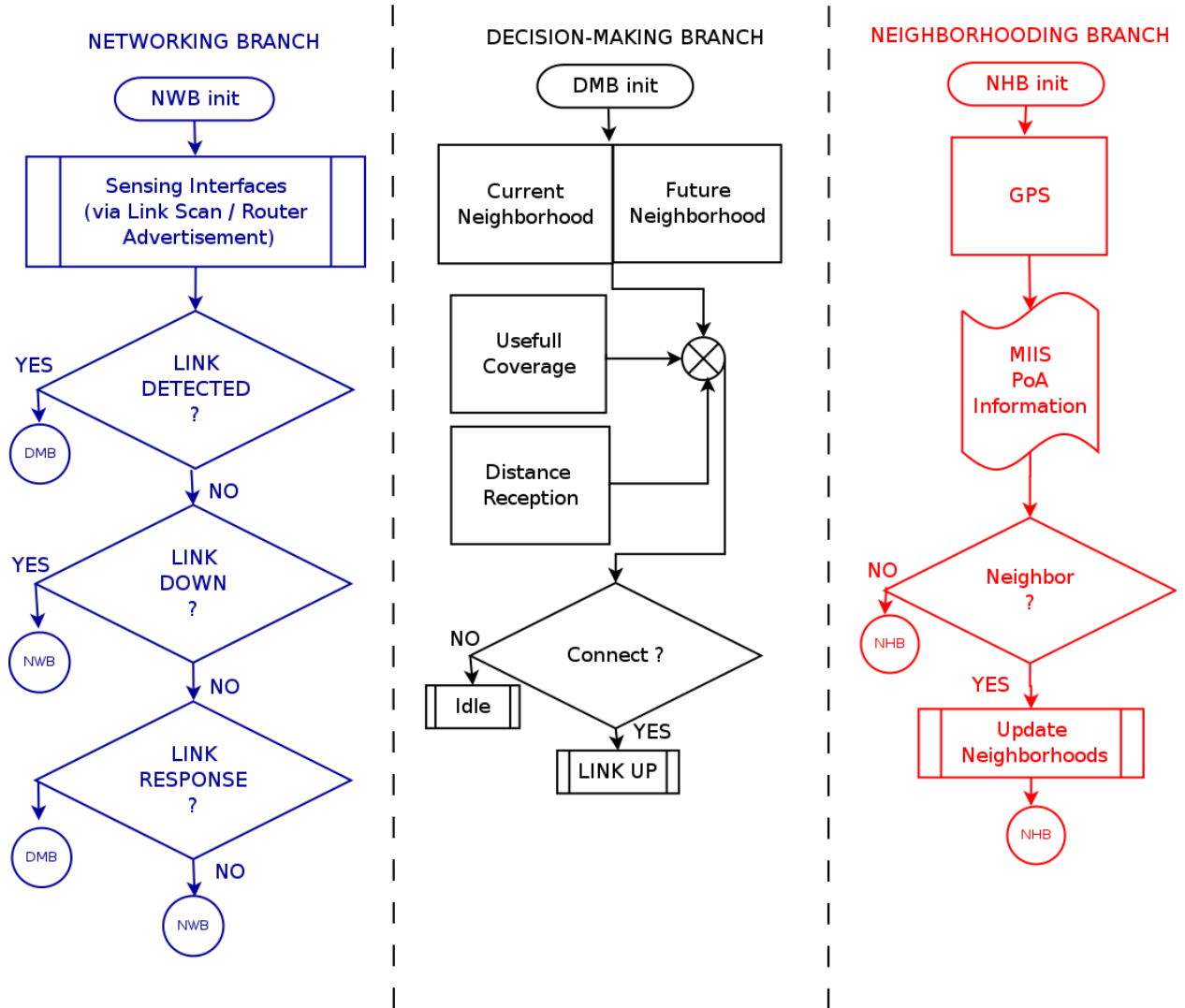


Fig. 1. Proposed VHDA algorithm.

ing at 32 Km/h from Universitat de Valencia Campus to Universitat Politècnica de Valencia Campus in the city of Valencia, Spain. Figure 3 shows the route from one place to another, involving a distance of 5.5 km in a 3.75 km² area. In this context we deployed 1 UMTS, 8 Wi-Fi, and 3 WiMAX PoAs covering different areas and with heterogeneous capacity, as illustrated in figure 4. It is important to point out that UMTS covers the whole area, meaning that the UMTS technology is always the backup connectivity technology for this set of experiments. Table I presents the main configuration parameters for the experiments. In the experiments, the OBU requests a 1.48 Mbps Constant Bit Rate (CBR) video traffic stream.

V. PERFORMANCE EVALUATION

To evaluate the performance of the proposed VHDA, we have also compared it against two different VHDA. We briefly describe the main decision-making process of those alternative algorithms:

- **Tech-Aware VHDA.** It takes into account only the theoretical bandwidth offered by the underlying technologies. So, whenever the car

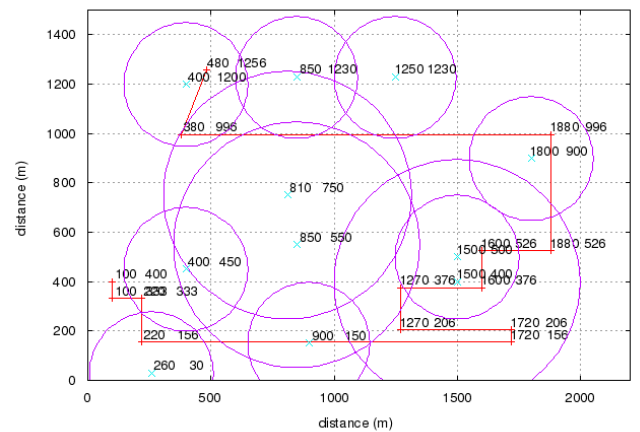


Fig. 4. Coverage grid.

finds a new coverage area of a technology with higher theoretical bandwidth, the VHDA connects to the new PoA. It makes use of two IEEE 802.21 services: MICS and MIES.

- **Cell coverage-based VHDA .** It uses the car's current and future geolocation, neighbor-

TABLE I
SCENARIO COMPONENTS.

Component	Wi-Fi	WiMAX	UMTS
Access Point	8	3	1
Theoretical Bw (Mbps)	54	70	5
Bw offered (Mbps)	28.2	16.3	2.7
VHO latency (ms) [12], [13]	1080	2665	-
Advertisement Interval (ms)	100	5000	-
Coverage (m)	500	1000	5000

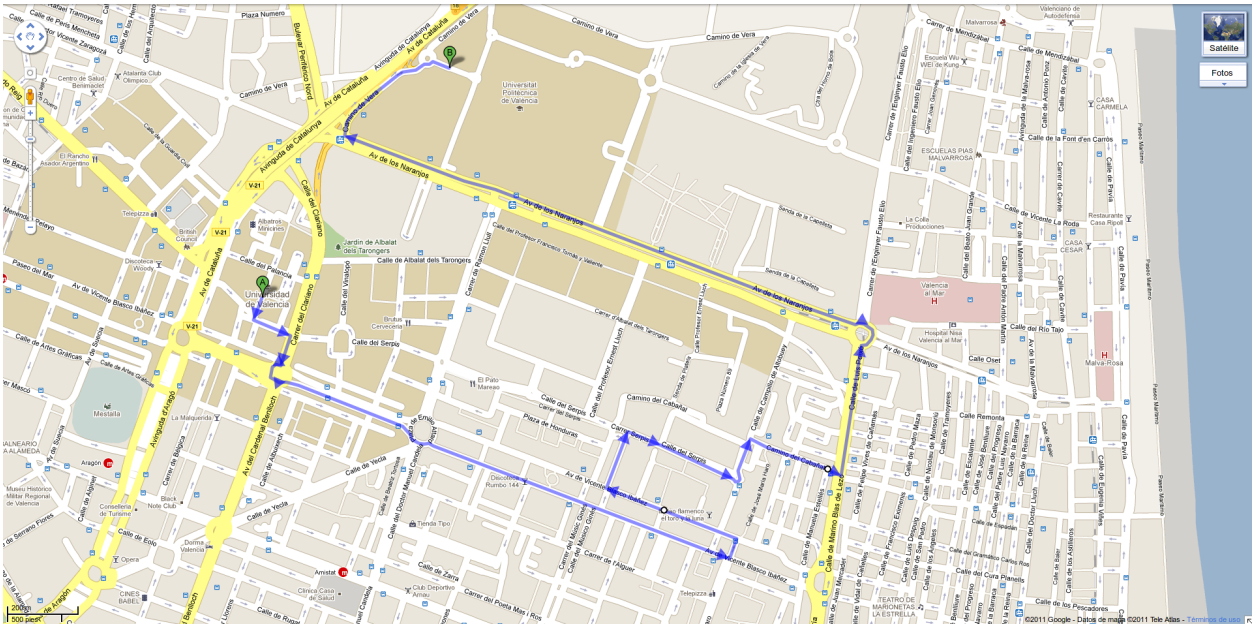


Fig. 3. Map layout.

hooding, and the three IEEE 802.21 services: MICS, MIES and MIIS. It considers the useful coverage time depending on the PoA coverage area and the route calculated by the GPS.

The handovers performed by the evaluated VHDAs are presented in Figure 5. As we can observe, Figure 5(a) shows the coverage resulting from the Tech-Aware VHDA and Cell coverage-based VHDA. Tech-Aware VHDA performed up to 18 VHO events due to its decision-making policy. Cell coverage-based VHDA performed about 15 VHO events, being more selective when switching from one network to another. In Figure 5(b), our proposed algorithm behaves in the same manner, performing up to 11 handovers, whether the minimum packet delivery threshold is set to 40% or 60%. The main difference consists on the geolocation (QoS border) where the handover has occurred.

Figure 6 presents the technology use dwell-time per VHDA. It summarizes the interfaces connectivity depending on the decision-making by the VHDA.

We have also evaluated the mean throughput obtained by each algorithm. Table II shows that the throughput per technology is also increased when applying more sophisticated VHDA; as switching to a

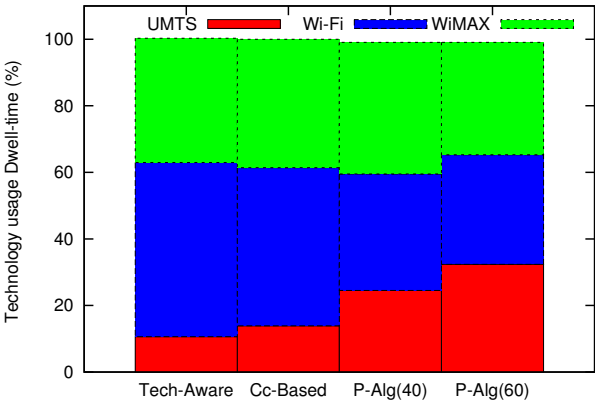


Fig. 6. Dwell-time comparison

new network only occurs when the QoS is guaranteed by taking into account the QoS border, as per our proposed algorithm.

VI. CONCLUSIONS

We have presented and evaluated a Vertical Handover Decision Algorithm that allows heterogeneous wireless vehicular communications. The algorithm considers the geolocation and navigation information and network context to guarantee the QoS of

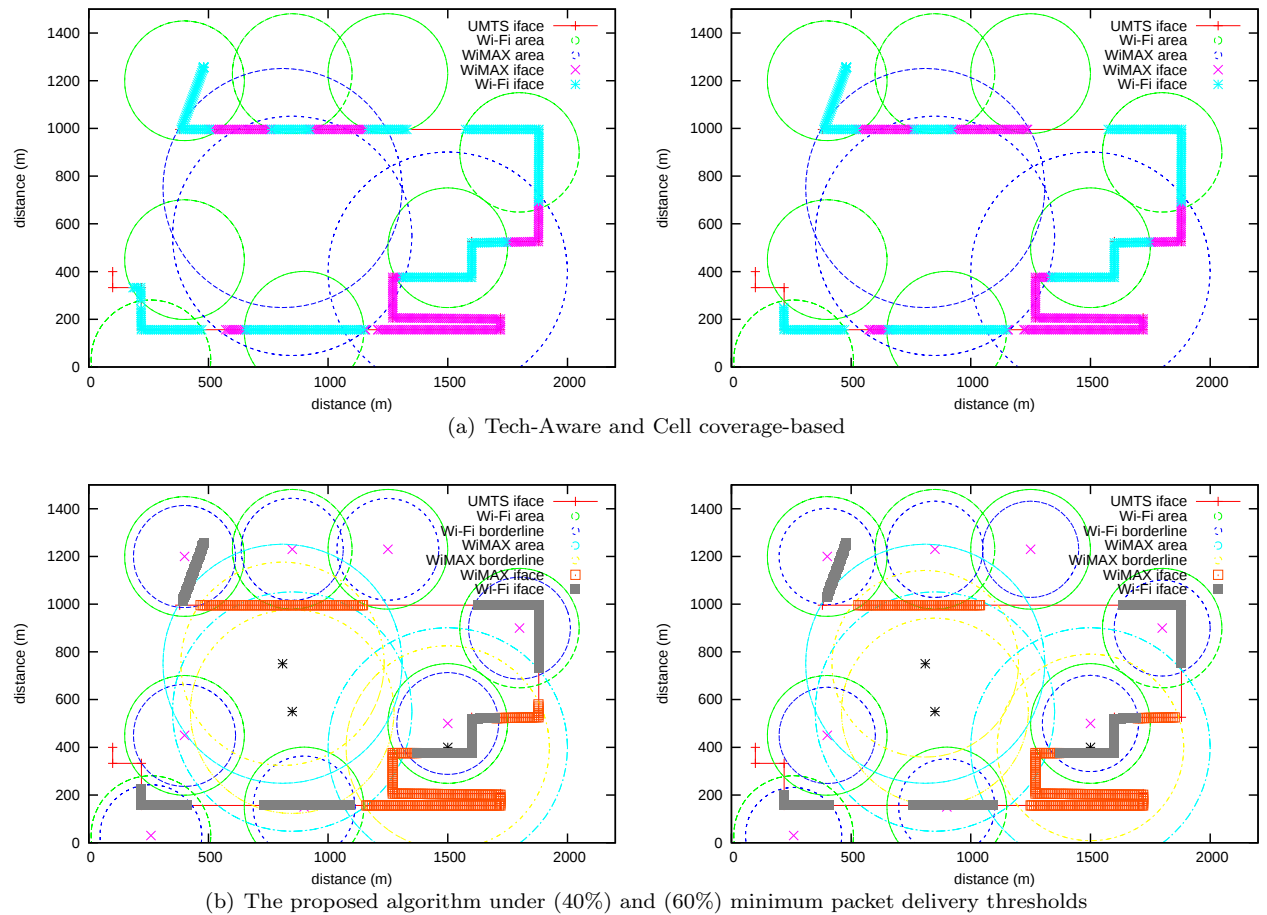


Fig. 5. VHDAs Handover comparison

TABLE II
MEAN THROUGHPUT COMPARISON (MBPS)

Technologies	Tech-aware	Cell coverage-based	Proposed algorithm 40%	Proposed algorithm 60%
Wi-Fi	1.1436	1.239	1.446	1.441
WiMAX	1.090	1.072	1.181	1.232
UMTS	1.406	1.407	1.411	1.421

the chosen candidate by taking into account realistic propagation models for underlying wireless networks such as Wi-Fi, WiMAX and UMTS, thus improving the correct flow transition from one PoA to another. Through a case of study, we have demonstrated that the proposed algorithm guarantees data flow switches to a similar or better network than the current one used, thus boosting performance in comparison to other solutions.

ACRONYMS

CBR	Constant Bit Rate.....3
GPS	Global Positioning System.....1
MCDM	Multiple Criteria Decision-Making.....2
MICS	Media Independent Command Service..2
MIES	Media Independent Event Service.....2
MIIS	Media Independent Information Service.2
MIPv6	Mobility support for Internet Protocol

ns-2	v.6.....2
Network Simulator	2
On-Board Unit	1
PoA	Point of Attachment.....1
QoS	Quality of Service.....1
RA	Router Advertisement.....2
RS	Router Solicitation.....2
UMTS	Universal Mobile Telecommunications System.....1
VHDA	Vertical Handover Decision Algorithm..1
VHO	Vertical Handover.....1
VN	Vehicular Network.....1
Wi-Fi	Wireless Fidelity.....1
WiMAX	Worldwide interoperability for Microwave Access.....1

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REFERENCES

- [1] “IEEE standard for local and metropolitan area networks- part 21: Media independent handover,” Tech. Rep., 2009.
- [2] A. Dutta, S. Madhani, W. Chen, O. Altintas, and S. Cai, “GPS-IP based Fast-handoff for Mobiles,” in *3rd New York Metro Area Networking Workshop*, Sept. 2003.
- [3] M. Ylianttila, J. Makela, and K. Pahlavan, “Analysis of handoff in a location-aware vertical multi-access network,” *Elsevier Computer Networks*, vol. 47, no. 2, pp. 185–201, Feb. 2005.
- [4] J. Montavont and T. Noel, “IEEE 802.11 Handovers Assisted by GPS Information,” in *IEEE International Conference on Wireless and Mobile Computing, Networking and Communications.*, 2006, pp. 166–172.
- [5] W. D. Hsiao, Y. X. Liu, and H. C. Chao, “An intelligent WiMAX mobile network handoff mechanism with GPS consideration,” in *International ACM Conference on Mobile Technology, Applications, and Systems*, New York, NY, USA, 2008, ACM.
- [6] J. Marquez-Barja, C. T. Calafate, J. C. Cano, and P. Manzoni, “A geolocation-based Vertical Handover Decision Algorithm for Vehicular Networks,” in *IEEE 37th Conference on Local Computer Networks (LCN)*, Oct. 2012, pp. 360–367.
- [7] E. Stevens-Navarro and V. W. S. Wong, “Comparison between Vertical Handoff Decision Algorithms for Heterogeneous Wireless Networks,” in *63rd IEEE Vehicular Technology Conference*, May 2006, vol. 2, pp. 947–951.
- [8] K. Fall and K. Varadhan, “ns Notes and Documents,” The VINT Project. UC Berkeley, LBL, USC/ISI, and Xerox PARC, June 2009.
- [9] Advanced Network Technology Division- National Institute of Standards and Technology, “Seamless and Secure Mobility,” <http://www.antd.nist.gov/seamlessandsecure/>.
- [10] B. V. Ericsson Telecommunicatie, “EURANE - enhanced UMTS radio access network extensions for ns-2,” .
- [11] J. Marquez-Barja, C. T. Calafate, J. C. Cano, and P. Manzoni, “MACHU: A novel vertical handover algorithm for vehicular environments,” in *IEEE Wireless Telecommunications Symposium (WTS 2012)*, Apr. 2012.
- [12] S. L. Tsao, Y. L. Chen, and C. H. Chang, “Evaluation of Scan and Association Process for Real-Time Communication in Mobile WiMAX,” *IEEE Transactions on Wireless Communications*, vol. 9, no. 11, pp. 3320–3323, Nov. 2010.
- [13] S. J. Yoo, D. Cypher, and N. Golmie, “Predictive link trigger mechanism for seamless handovers in heterogeneous wireless networks,” *Wirel. Commun. Mob. Comput.*, vol. 9, no. 5, pp. 685–703, 2009.

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