

First Person Shooters on the Road: Leveraging on APs and Vanets for a Quality Gaming Experience

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Abstract—This work studies the feasibility of using on the road 802.11 Access Points (APs) for the support of First Person Shooter (FPS) games, which are among the online services that exhibit the tightest real-time requirements nowadays. After demonstrating that an acceptable quality of service can be guaranteed, we propose and assess the extension of the AP coverage area by means of vehicular ad-hoc (VANET) communications. The time for which a game can be played in a satisfactory manner can be, in fact, increased exploiting neighboring vehicles, thus improving the general gaming experience. To this aim, we adopted a subjective quality estimator, which reveals whether a game could, or could not, be properly run in a given scenario. Our simulation results show that the AP coverage area can be significantly increased when using other cars as packet forwarders, while maintaining the subjective quality at acceptable levels. All this is performed assessing the feasibility of FPSs on realistic vehicular traffic traces, obtained recording over 100 traversals of an urban road under varying traffic conditions.

Keywords- *Inter-vehicular communications; Online Games; Real-time Services; Quality of Experience; First Person Shooter*

I. INTRODUCTION

In the past few years, mobile devices have gained an increasingly important role in the computer gaming arena. More and more mobile customers, in fact, fill up their idle intervals of time (e.g., on the bus, going to work) playing some game while on the move. The vast majority of such games is either individual or turn-based, thus do not critically depend on network latency. Hence, for such type of games, the role played by wireless connections is limited to providing a fast download of the desired app. However, interactive multi-player games, as First Person Shooters (FPSs), racing games or Massively Multiplayer Online Role Playing Games (MMORPGs), are also expected to reach a high share of users in mobile scenarios in the next few years [1]. Many of such games are based on client-server architectures, where game providers deploy and maintain servers equipped with adequate levels of bandwidth and processing power. Nevertheless, the gaming quality experienced by a given player strongly depends on the performance of the connection set up between his/her device and the server that his/her handheld joined.

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Interestingly, the use of mobile devices is also expected to become popular within the context of moving vehicles, as more and more vehicles will become equipped with 802.11 interfaces, and be able to support Internet connections through vehicular-to-vehicular (V2V) and vehicular-to-infrastructure (V2I) communications. In fact, although the 802.11 standard was not initially designed for supporting communications on moving vehicles, this technology is being adopted to also support such type of scenarios [2], [3], [4], [5]. Hence, many research initiatives have proposed applications based on the use of V2V and V2I communication paradigms. Among these, relevant streams of work have investigated how accident prevention applications, as well as traffic management ones, could put to good use the exchange of messages between cars [6]. None of these, however, envision the support of real-time streams between a moving vehicle and a server.

Now, if vehicular networks will become true, we can imagine future situations where passengers (e.g., kids in the back seat) will spend their time engaged with their mobile devices while connected to the Internet, playing their favorite FPS or MMORPG games against other players that are connected from elsewhere to the same gaming arena.

Clearly, this will be possible only if an adequate quality of service will be provided to those mobile players. In order to verify the feasibility of such scenario, we here consider two, apparently unrelated, problems: on one hand, how to satisfy the real-time requirements of online games, on the other hand, how wireless infrastructures can be exploited to provide connectivity to moving vehicles. Hence, a first contribution of this work is a feasibility study that assesses the use of 802.11 for the provision of satisfactory levels of quality of service to multi-player games inside moving cars. Provided this possibility, the second and most relevant contribution of this work is the support of real-time services through the use of V2V connections that extend the coverage area provided by APs: if a WiFi-enabled car is inside AP coverage, it serves as a forwarding relay to and from those neighboring vehicles that fall outside. In fact, the enlargement of the coverage area translates into a longer connection time, thus improving the gaming experience. This is the scope of this work: we explore the feasibility of providing satisfactory quality of service levels to real-time applications, such as FPS games, in a vehicular scenario through the combination of V2I and V2V connections. Our contribution differs from any previous work, which exploited the use of “traditional” applications [2], [3], [7], e.g.

file transfer or web browsing, as the requirements imposed by FPS games on the underlying network are way more stringent. This type of applications, in fact, are very challenging for wireless networks, since a high quality experience requires high levels of interactivity [8], [9], thus implying tight limits for delay, jitter and packet loss.

To fulfill our analysis, we selected a FPS game as a relevant exemplar of a real-time application. In such game a given user controls an avatar who has to accomplish a mission or kill all the enemy characters in a virtual scenario. Clearly, in such situation, responsive movements, which generate fast paced inputs to the game, are very important. These generate considerable amounts of UDP packets per second (up to 85), but of small size (typically a few tens of bytes of payload) [10]. We tested such game running, in simulation, on a vehicular network, where vehicles moved with realistic running patterns along an urban road, as they were drawn from over 100 traversals performed with our cars in reality.

The rest of the paper is organized as follows: the next section talks about the related work. The scenario of interest is explained in Section III. Section IV shows the achievements and results, and the paper ends with the Conclusions.

II. RELATED WORK

Since we are studying the feasibility of 802.11 for real-time applications, in this section we will summarize the state of the art regarding: (a) the use of 802.11 APs for providing connectivity on the road, and, (b) the problem of estimating subjective quality for real-time applications.

A. Using 802.11 in Vehicular Scenarios

The performance of a WLAN for vehicular connectivity was measured in [11] for different scenarios. A connectivity range of 1,000 meters was achieved in some cases. In [2] the use of 802.11 APs for connecting moving vehicles was also studied. Three different phases were observed: connection, disconnection, and a “production” one, where most data exchanges occurred. The maximum throughput obtained was about 5 Mbps.

In [7], the authors explored the feasibility of communications between a moving vehicle and an 802.11-based AP. The tested services were TCP bulk transfers, UDP flows and web browsing. Some of the tests included a backhaul network segment, in order to emulate the Internet. One of the authors’ conclusions was that performance degradations were not only given by the use of wireless links. Backhaul network bandwidth limitations and delays, in fact, also had very harmful effects on the experienced throughput.

In [3] a system named Cabernet was proposed to deliver data to and from cars using 802.11b/g APs, as their offered bandwidth is notably higher than the one available through cellular networks. The system was thought for delay tolerant applications that could exploit opportunistic connections, i.e. not needing a continuous exchange of data with a server (e.g. transmitting data from sensors, message delivery). Thus, this system was proposed as a suitable complement to 3G and 4G networks: by setting a number of APs, spatial reuse of the same

frequencies can provide a good connection method. In contrast, what we are here studying is the suitability roadside 802.11 APs for the delivery of real-time services such as FPS games.

In [12] vertical handoffs in a scenario considering a cellular network in addition to a WLAN were studied. In addition, the authors considered the possibility of using V2V communications to extend the coverage of the WLAN.

A protocol for V2V communications was proposed in [13] in order to broadcast messages, mainly about traffic, weather or even advertisements. It used the predictability of the car’s movements in order to improve the efficiency of channel utilization.

B. Subjective Quality Estimators for Online Games

The idea of obtaining an estimator of the QoE of a service, as a function of objective network parameters, was first developed for VoIP. The E-Model [14], proposed by ITU, is able to generate an estimate of the expected Mean Opinion Score (MOS) of a given service, which ranges from 1 (bad quality) to 5 (excellent). The input variables are network parameters (delay, packet loss), and also the codec and other factors that can deteriorate the voice quality. Logically, the model is developed from surveys in which real people are involved.

In [15] a quality estimator was also developed for a FPS game (*Quake IV*). Although the bandwidth of these games is typically small (some tens of kbps), they have very stringent real-time requirements. This quality model uses delay and jitter as input variables, since the game implements a very effective packet loss concealment method [16].

In this work we have decided to use a FPS game because it constitutes an example of a service with really tight real-time requirements, in which delays above 150 ms would be intolerable by any user [16]. In addition, the use of a subjective quality estimator provides more interesting results, since we not only obtain the objective parameters from the network, but we also integrate them into a single figure estimating the user’s experience with the service.

III. SCENARIO OF INTEREST: MODELING AND SIMULATION

As reported in [3], 802.11 APs are being used in some cities as a means for connecting to the Internet. The performance of 3G and 4G networks and their high costs are still a barrier for their widespread use with all applications, as online games. What is interesting, instead, is that throughout the most urbanized areas, in the western world, many restricted access APs, but also many open ones, are densely distributed. The latter ones, hence, can be exploited for the provision of applications to customers on the move.

In fact, the first challenge we are trying to explore in this work is the possibility of using a multimedia application in this scenario. Thus, we will simulate a street with a single AP partially covering it (Fig. 1). We here select a 2 km long road: as shown in a recent study, it can be considered a typical length in an urban setting [17].

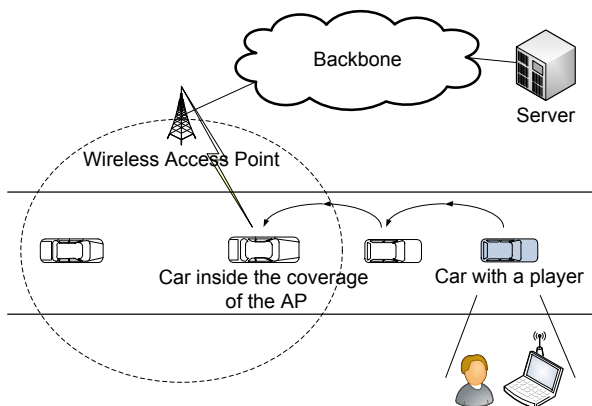


Figure 1. 802.11-enabled cars used for relaying packets to the AP

The second objective of the tests is exploring the feasibility of increasing the time a player can use a multimedia application, i.e. for how long a car outside AP coverage can keep using the application, while other cars forward its packets to and from the AP (Fig. 1). So, in this second scenario, other WiFi-enabled cars create an ad-hoc network. In this section we will describe the tools we have used to model the scenario and obtain the results.

A. Simulation Settings

An ns2 simulation scenario (Fig. 2) has been developed, including a street with an 802.11 AP, having direct visibility with a road. Every second, a new car appears at the beginning of the street. There is a Fixed Node (FN), which simulates the game server, connected via the Internet to an AP. A hierarchical network address structure has been set in the simulator, in order to make the AP forward packets between the wired and the wireless networks. Some of the cars are running a FPS game, which consists of two UDP flows, one for the uplink and another one for the downlink. If the car running the application is outside the coverage area of the AP, other cars can forward the packets by the use of an ad-hoc routing algorithm. The default parameters of the simulations have been included in Table I.

B. Generation of Game Traffic

In order to generate realistic traffic, traces captured from real games have been obtained from [18]. Each client sends 64 pps to the server, with an average size of 79 bytes (40.5 kbps). The server traffic corresponds to a gaming arena with 5 players, generating 14 pps with an average size of 161 bytes (18 kbps).

C. Calculation of the MOS

As we have previously said, in [15] a subjective quality estimator (G-Model) was proposed for a FPS game (*Quake IV*), as a function of delay and jitter. The model was obtained by deploying a number of parties with real players, while modifying the network in order to artificially introduce delay, jitter and packet loss. Surprisingly, packet loss did not disturb while below 35%, so the authors decided to consider the MOS only dependent from delay (measured as round trip time) and

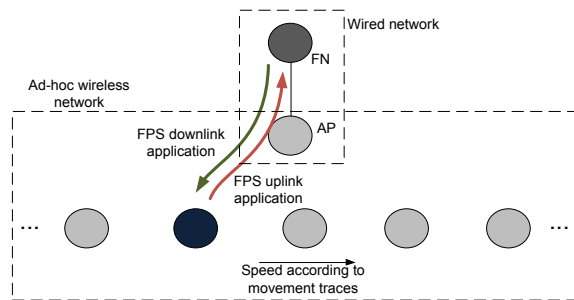


Figure 2. Scenario used in the simulations

TABLE I. SIMULATION PARAMETERS

Parameter	Value
Propagation model	Two Ray Ground
Street length	2000 m
Street width	10 m
Time between cars	1 sec
Access Point and nodes coverage radius	250m
Access Point position	1000 m
802.11 rate	54 Mbps
Ad-hoc routing algorithm	DSDV
Update period of DSDV	0.5 sec
One Way Delay Access Point-Fixed Node	20 ms

jitter (measured as the standard deviation of the delay). Multi-dimensional regression analysis was used so as to obtain the model. First, an impairment parameter X is obtained:

$$X = 0.104 \text{ ping_average} + \text{jitter_average} \quad (1)$$

And the MOS, ranging from 1 to 5, is calculated using:

$$\text{MOS} = -0.00000587 X^3 + 0.00139 X^2 - 0.114 X + 4.37 \quad (2)$$

We will present the MOS as the average value for all the packets received within a time interval of one second. When packet loss is above 35%, we will consider MOS to have a value of 1. Some works use the same MOS scale of VoIP, and consider it acceptable above 3.5. Nevertheless, some others consider that a value of 3 can be good [17]. Players have been observed to change game server when their average MOS reaches a value of 2.

IV. ACHIEVEMENTS AND RESULTS

In this section, we want to answer a few questions. First: is it possible to experience a good MOS for a FPS in a vehicular scenario? Second: how much can we extend the coverage area of an AP with the use of a hybrid V2I-V2V network infrastructure? Third: what happens if we use real movement traces? Finally, we will study the effect of background traffic on the QoE of the game.

A. Can we obtain a good MOS in a vehicular scenario?

To answer this first question, we deployed a test, in which a single car running a game moved along the street at a constant speed of 50 km/h, while directly communicating with the AP. In Fig. 3 we present the MOS, which is always above 3.7. Although not shown in the figure, the delay is about 42 ms, and jitter roughly 0.5 ms; both of these quantities present a very constant behavior while the car is in the coverage area. An average delay equal to 42 ms means that its value is mainly determined by the fixed network (40 ms). This result demonstrates the first idea proposed in this work: an AP is able to provide acceptable communications quality for the applications of interest in the given scenario. Logically, this only happens while the car is inside its coverage area.

B. Can we extend the coverage area keeping good MOS values?

Next, we want to test the feasibility of using V2V communications in order to extend the coverage area of the AP. For this purpose, we have deployed a simulation in which 300 cars flow down a single lane street and create an ad-hoc network. The 150th car runs a FPS game (in order to have the street “full with cars” when it enters the road), while, again, all cars move at a constant speed of 50 km/h. We present the results for a representative single run, which will help us understand the phenomena that occur in this scenario. Average values, as well as their corresponding confidence intervals will be presented in the next subsection.

Fig. 4 presents the MOS. From the figure, it can be seen that, as soon as the car enters the street, it starts receiving and sending packets by means of the VANET. Although the initial gaming quality is not acceptable, since the game uses UDP, it keeps sending packets despite the fact that they are not received. Now to better understand the results, in Fig. 5 we have included (a) delay, (b) jitter, (c) packet loss and (d) the number of ad-hoc hops of downlink packets. During the initial 292 meters, the quality is not acceptable because the ad-hoc protocol keeps updating routes, producing jitter and loss peaks. This can also be seen in Fig. 5 (d), where an oscillation in the number of hops can be observed. When more than 300 meters have been travelled, the delay and the jitter peaks are reduced as fewer hops are traversed, so the MOS becomes acceptable until the car enters the AP coverage area. Once the car gets out of the coverage area, a “handoff” can be observed, associated with an increase of the delay, caused by the time the ad-hoc protocol needs to find a new route. After that, a zone in which the MOS is again acceptable can be observed. But, why does this “handoff” phenomenon not appear when the car enters the AP coverage? In fact, when the car passes from a situation with V2V connectivity to another one with direct AP connectivity (i.e., V2I), no packets get lost. Hence, once the car is in the AP range, it directly sends its packets to the AP. On the other hand, when the car leaves the AP coverage, some time is needed to readjust the routes of the ad-hoc routing protocol. Different routing algorithms may present different behaviors, but this is beyond the scope of the present work. In [20] different schemes for V2V and for V2I mobility management were discussed.

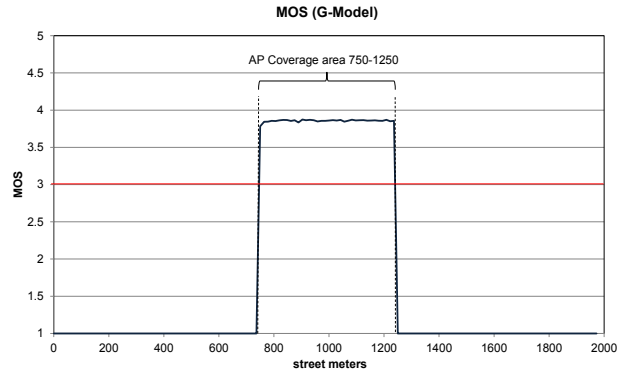


Figure 3. MOS for a single car, not using V2V communications

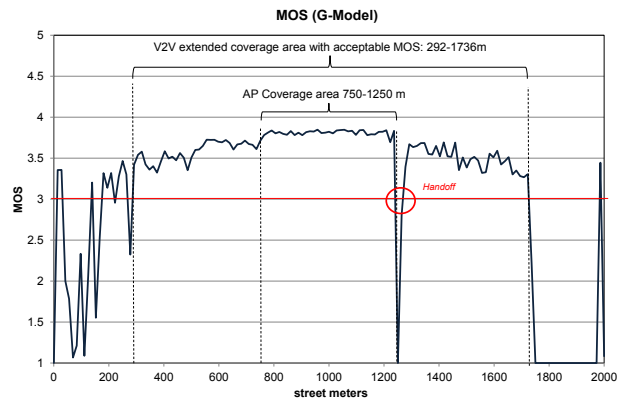


Figure 4. G-Model MOS for the V2V scenario

However, the phenomenon we observe here is a sort of “V2V to V2I handoff”, which may require specific algorithms in order to be correctly managed. A survey of routing protocols for these scenarios can be found in [21]. A cost and delay study of handoffs in a similar scenario can be found in [12]. All in all, the coverage area has been extended in this case from 500 to 1,444 meters (288%) by the use of V2V communications.

C. What if we make it even more realistic?

The previous results have been obtained imposing a constant speed to all cars. In this subsection we will consider a more realistic scenario in which car movements have been simulated using 111 traces obtained from a real car moving on Via Benedetto Croce, Pisa, Italy [22]. The traces have been divided into five groups, according to their average speeds, and each test is deployed using traces from one of the groups. Again 300 cars are sent in our simulation, and car #150 runs the game. Each car randomly selects a movement traces within a group, thus allowing us to compare different traffic density situations. The average speeds of the traces range from 8.4 to 29.1 km/h. For each car, “contact time” is defined as the duration of the longest interval with acceptable MOS. When the average MOS degrades for more than two seconds, this is considered a severe quality disruption that ends a contact between the vehicle and the AP.

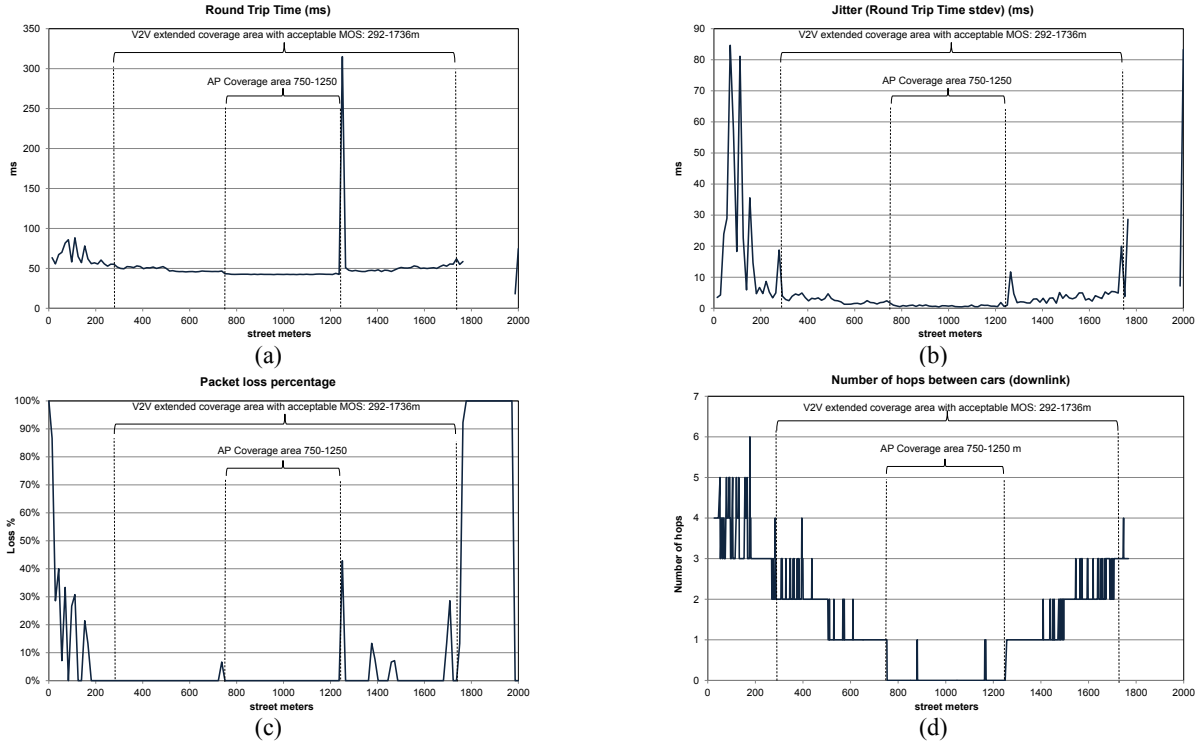


Figure 5. Scenario including V2V communications: a) Round Trip Time; b) Jitter (stdev of Round Trip Time); c) Packet Loss; d) Number of V2V hops

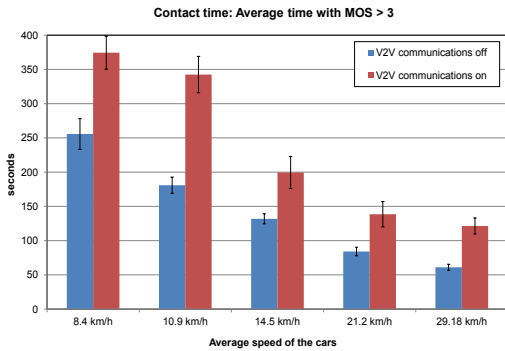


Figure 6. Average connection time with good quality

Fig. 6 presents the average duration of the contact time, with and without the use of V2V. Each test has been repeated 10 times, and 95% confidence intervals are also presented. The value of the X-axis is the average speed of the traces of each group. It can be seen that the improvement achieved by the use of inter-vehicular communications is significant (in some cases the contact time is doubled), since the average time passes from the one corresponding to the AP coverage to an enhanced one. It can also be observed that contact time variance is smaller when no V2V connections are used, since the game only works while being in the coverage area of the AP.

D. On the negative effect of TCP background traffic

In this subsection we will study the effect of background traffic on the QoE of the game. By now, we have only considered cars running the FPS game. The next tests also

include some cars running an FTP download. A FTP download can heavily deteriorate gaming quality, since TCP increases its transmission window until a packet is lost, and this tends to produce a saturation of the available bandwidth. Different mechanisms for controlling TCP bandwidth have been proposed, in order to grant the feasibility of real-time services in this scenario: e.g. [23] studied the use of intelligent APs to limit the maximum value of the TCP advertised window. We have done the same test run in IV.B, but this time, in addition to car #150 running a FPS, the car that follows (car #151) runs a FTP download, using TCP SACK. Fig. 7 (a) shows the throughput of the FTP application. Fig. 7 (b) and (c) present the MOS and the jitter of the FPS car, respectively. It can be seen that the FTP flow jeopardizes the beneficial effect of the VANET, only permitting the game to be continuously played within the coverage area, although with a low quality.

V. CONCLUSIONS

This article has studied the feasibility of using 802.11 networks for providing connectivity to the use of FPS games. It has been shown that these networks are capable of providing a good subjective quality for real-time online gaming. In addition, V2V communications have been used to extend the coverage area of an AP. Tests with real movement traces have been performed, in order to measure the increase of the time where the quality of service is acceptable, when using V2V communications. The results show that V2V can significantly increase the time that the game can be played with quality inside the car. On the other hand, tests with FTP background traffic reveal the need for mechanisms that limit their bandwidth, as their presence heavily deteriorates the quality of

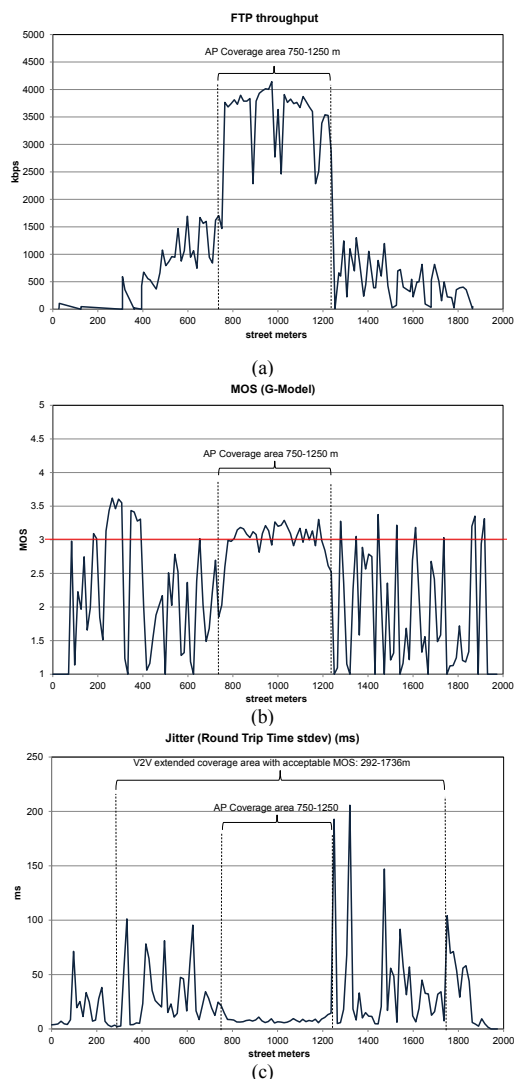


Figure 7. FPS and FTP competence: a) Throughput of the FTP download; b) MOS of the FPS game; c) Jitter of the FPS game

FPS games. As future work, we want to extend the study to the situation in which different numbers of cars are running the game, hence also introducing synchronization issues [24]. In addition, we plan to build an agent that, exploiting the contact times that may occur between a car and an AP, offers a player different types of gaming experiences depending on the network status.

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