Performance Evaluation of Unmanned Aerial Vehicles for video based Surveillance Applications

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Abstract

It is always beneficial to look for latest technology introduced so far to ensure proper surveillance. In recent times, unmanned aerial vehicles (UAVs) represent a new potential market and have appealed a lot of attention. UAVs serve a lot for law enforcing agencies for constant video surveillance at remote locations in rural areas where otherwise required a lot of resources. Airborne monitoring through camera mounted UAVs assists to capture the real time streaming video from different vantage points to a single commanding and controlling unit. We suggest a UAV based framework that would lead to a timely action in any criminal activity or disaster prevention. In this paper we analyzed the throughput of indoor UEs and outdoor UEs of one such video streaming system by using a model of wireless propagation, multipath propagation loss, shadowing and fading.

1 Introduction

For the constant and proper video surveillance of any area in a remote location, it is always a good practice to use modern technology instead of human physical interaction. In recent times the modern electronic spy's, camera mounted Unmanned Aerial Vehicles (UAVs) can be used to achieve this objective [1]. UAVs serve in surveillance of farms, floods, highway traffic monitoring [2], terrorism, natural disaster prevention etc. We cannot ignore the probabilities of terrorist attacks especially in the buildings positioned at distant urban or open areas; here we are concerned with the performance of video surveillance of such buildings.

There are several vantage points that exist in indoor and outdoor of such sites whose surveillance is supposed to be carried out. We have suggested a two tiered design for closed circuit aerial monitoring for the kind of scenario. For this work we used Wireless 4G LTE technology based on cellular infrastructure (Figure 1).

For real time video streaming, several indoor and outdoor cells are used which we called femto cells and macro cells respectively in this structural design to construct a closed circuit monitoring framework.

The topological concept and related terminologies are adopted from 3GPP R4-092042 standard. There are several camera mounted UAVs in this architecture. As far as indoor framework is concerned; we have certain UAVs inside the building that are part of femto cells referred to as home UEs responsible for the transmission of real time video to their relevant base stations called home ENBs. In the similar way outdoor framework consists of outdoor macrocells where UAVs are flying constantly, referred to as macro UEs whom duty is to convey video in real time

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to their corresponding base stations mentioned as macro ENBs. For Enhanced Node we used the word ENB whereas for User Equipment we used the term UE.

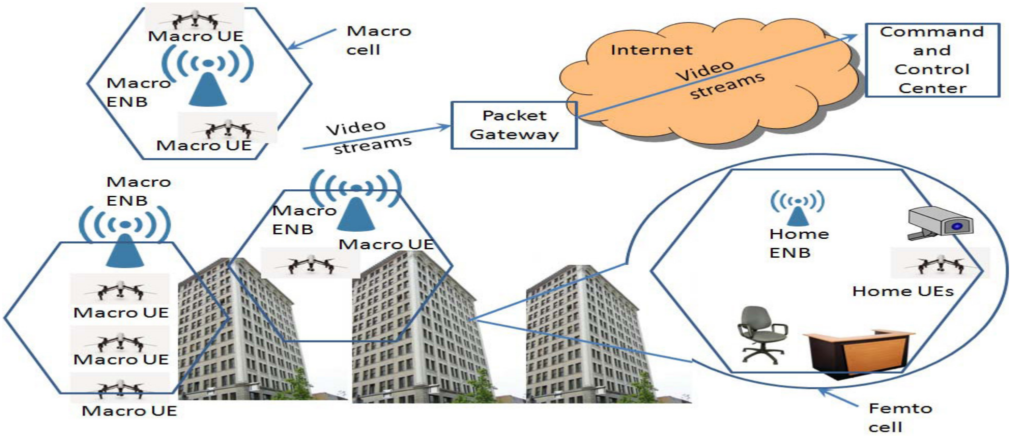

Figure 1: Two tiered Building Surveillance System comprising both Macro and Femto Cells

Indoor and outdoor captured streams of video are simultaneously transmitted to a single command and control center over Internet link. Topological structure of such kind would lead to well-timed action in wrongdoing or disaster avoidance.

Following are our contributions in this work.

(1) For appropriate real time video surveillance of different vantage spots outside and inside the buildings located at remote location in urban or open areas, we suggested a two tiered architecture using multi UAVs that are camera mounted.
(2) Investigating the consequences of wireless propagation set-ups to examine the end results of distortion in wireless signal because of multipath propagation at applied flying speeds of UAVs and signal propagation loss also known as shadowing loss over towering building infrastructures and; (3) Analysis of the Quality of Service (QoS) of such a multi-UAV framework supporting real time video streaming with video format encoded in MP4.

Under the 4G LTE standards, for macro cell we operated models supporting flight patterns of UAV. To accomplish this we took into our consideration the actual frequency band (2.1 GHz) and handover algorithms for smooth mobility for the proper communication of wireless nodes. At the end, we used Network Simulator-3 (version 3.26) to endorse our work by simulating our experiments [3].

2 Related Work

Very important survey paper on Flying Adhoc Networks (FANETs) by Becmezci et al [4] highlighted the capability of FANETs in recent applications. Another new direction given by Eckert et al [5] explored new propagation models for newly introduced application in Aerial Adhoc Networks like communication among paragliders during flight; prior to that several researchers have supposed simplistic LoS propagation models in their research because of the high flying altitudes of UAVs.

For maximum network connectivity, Haibo et al [8] have considered the Airborne Networks nodes placement; though in their study UAVs are serve as the relay point in the sky for mobile nodes while on ground it is impossible that UAVs reach each other without the flying UAVs; in contrast in our study we did not focus the placement of nodes on the ground and supposed all nodes to be mobile in air in constant flight.

Previously in recent research, researcher like Sahingoz in his paper [6] [7] discussed the issues involved in networks support mobility using multiple UAVs in flying communication and raised various interesting queries on path planning, QoS and protocol suitability but did not concentrate on propagation model in his research. We tried in this paper to explore some of the unanswered issues of the performance of routing and real propagation models using a simulated environment in NS3.

3 Wireless Propagation Models Used

Multi-path propagation and shadowing are the major hurdles faced by wireless signal propagation as compared with wired signal propagation which corresponds to a deterministic model differs as per distance. We have used Friis propagation model under Line of Sight (LoS) signal propagation as shown in equation 1 mentioned below.

If we are talking about shadowing loss, it is the phenomenon when wireless signal has to go through hurdles (for instance walls); this condition occurs as there is no clear line of sight in between transmitter and receiver. On the other hand, the second major issue is fading or multipath propagation which is the phenomenon in which the wireless signals look discontinuous reception of LoS signals and reflected forms of signals from additional hurdles. Here we are interested to investigate the effects of shadowing loss in our infrastructure.

A Shadowing Loss

We have used Hybrid Buildings Propagation model as the standard model for indoor wireless signal propagation. This model is embedded in latest versions of ns-3 and its beauty is its multiple properties as it is the combination of ITU-R P.1238 for indoor communications, ITU-R P.1411 model for small range communications, Hata model and COST231.

$$P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi d)^2} \qquad (1)$$

$P_r(d)$ = Received power at distance d

P_t = Transmit power

$G_t G_r$ = Transmit and Receive Antenna Gains

Under different setups we used this model to examine the path loss. Table 1 given below represents the parameters for shadowing loss we used in this work as standard; where we had to introduce any variation in the simulation settings for any specific experiment we mentioned that explicitly in its experimental results in this paper.

Table 1. Building Propagation Model Parameters

LOS TO NLOS THRESHOLD	200 M
INTERNAL WALL LOSS	5 DB
STANDARD DEV OF THE NORMAL DISTRIBUTION TO CALCULATE SHADOWING DUE TO EXTERNAL WALLS	7
STANDARD DEV OF THE NORMAL DISTRIBUTION TO CALCULATE SHADOWING FOR MACROUES	8
STANDARD DEV OF THE NORMAL DISTRIBUTION TO CALCULATE SHADOWING FOR HOMEUES	5

4 Mobility Model for MacroUEs- Gauss Markov

In this work to mimic the actual real world flight pattern of outdoor UE which we called as macroUE, Gauss-Markov mobility model is used [9] [10]. This model uses three variables to update its pitch, direction and speed. The motion along z-axis is examined by the pitch variable while the direction and speed variable command the new direction and speed in the x-y plane. Equations 2, 3 and 4 are given below to show this.

$$s_n = \alpha s_{n-1} + (1-\alpha)\bar{s} + \sqrt{(1-\alpha^2)} s_{x_n-1} \qquad (2)$$

$$\theta_n = \alpha\theta_{n-1} + (1-\alpha)\bar{\theta} + \sqrt{(1-\alpha^2)} \theta_{x_n-1} \qquad (3)$$

$$p_n = \alpha p_{n-1} + (1-\alpha)\bar{p} + \sqrt{(1-\alpha^2)} p_{x_n-1} \qquad (4)$$

Parameters set for the simulation of Gauss Markov Model for our framework are given in Table 2.

As we have already discussed, our infrastructure is based on two types of user equipment's and these are home UEs and macro UEs. As macro UEs are constantly flying around the buildings, these nodes are considered being mobile; because of their mobility these camera mounted UAVs are frequently detached and attached from one macro ENB to another; the phenomenon is called handover as it happens normally in consistent cellular systems. The criterion of handover algorithms depend on the supreme received signal from the macrocell base stations.

Table 2: Gauss Markov Model Parameters to simulate mobility of macro UEs

Default PITCH	GAUSSIAN RV(BOUND=0.04, MEAN=0, VAR =0.02)
Default DIRECTION	GAUSSIAN RV (BOUND=0.4,MEAN=0, VAR=0.2)
Default VELOCITY	GAUSSIAN RV (BOUND=0, MEAN=0, VARIANCE=0)
Average PITCH	UNIFORM RV (Minimum =0.05, Maximum =0.05)
Average DIRECTION	UNIFORM RV (Minimum=0, Maximum=6.28)
Average VELOCITY	VARIABLE 1-10 M/S
Value of ALPHA	0.85
Assigned TIME STEP	0.5 SECONDS

In contrast the home UEs are assumed to be stationary in this work which means either these are miniature UAVs that choose resting position at any point inside the building (on a cabinet or window sill) to discover detection or these are fixed wireless IP cameras embedded discretely into walls of the rooms. Home UEs are connected with their base stations or access points that we referred as home ENBs. Inside the building remote host connectivity is established by an internet link over a protected and secure channel.

5 Simulation Environment and Parameters

As mentioned in Figure 1, we have adopted the network topology from 3GPP R4-092042 standard. NS-3 version 3.26 is used for performing all simulations. The standard parameters taken for this study are mentioned in Table 3.

6 Performance Evaluation

We analyzed the throughput of home UEs and macro UEs by changing different parameters. We did four experiments to judge the increase or decrease in throughput; two experiments for home UEs and two for macro UEs. We were also interested to find out the causes behind such an increase or decrease in throughput.

For the simulations we used Evalvid Client-Server application developed by GERCOM Group for ns3 [11]. Using this application the MPEG-4 encoded video was used for surveillance recordings of the buildings.

In contrast with the original GERCOM code we introduced some amendments; In the original GERCOM code macroUEs use a random waypoint mobility model while we used Gauss-Markov mobility model to mimic macroUEs, second in original code the video flows from remote hosts to the macroUEs/homeUEs but in our situation the videos are run by using UDP from the macroUE/homeUE to a remote host.

A Impact of Line of Sight to Non Line of Sight (Los2NLoS) threshold on throughput of MacroUEs

For this experiment, we simulated by varying the LoS2NLoS threshold from 200 to 300 with stepping 10 as shown in Figure 2. We observed very interesting trend of increase in average throughput of macroUEs; and it is natural phenomenon as more we go with larger LoS value, we found greater throughput as there is no obstacle found within the LoS range; hence the increase in throughput from urban towards open areas was analyzed. All the parameters are same as given in Table 3 except the values of LoS2NLoS threshold which we gradually increased for this simulation.

Table 3: Simulation parameters as per 3GPP R4-092042 specification

Rooms/apartments	4
Number of floors	4
Total number of femtocells	2-8
Total number of macroenb sites	1-4
Area margin factor	0.5
Density of macroue (number of macroues per square meter)	0.00002
Deployment ratio of homeenb	0.2
Activation ratio of homeenb	0.5
Homeues to homeenb ratio	1
Macroues/homeues	20 / 10
Macroenb /homeenb tx power	46 / 20 dbm
Macroenb dlearfcn / homeenb dlearfcn	100
Macroenb ulearfcn / homeenb ulearfcn	18100
Homeenb bandwidth (in terms of resource Blocks rbs)	100
Macroenb bandwidth (in terms of resource Blocks rbs)	100
Numbers of bearers per ue	1
Srs periodicity	80
Scheduler	Proportional Fair

B Impact of number of MacroENB sites on throughput of MacroUEs

By configuring in the settings of our simulation, we kept the maximum velocity of macroUEs constant i.e. 2m/s.

Increasing the number of macroENB sites decreased the average throughput of macroUEs as shown in Figure 3, the reason behind this decrease is handover among macroENB sites; as in limited distance of 500 meters we increased the number of macroENB sites, the faster switching of macroUEs occurred in handover from one macroENB site to another that resulted in the decrease of overall macroUEs throughput. So with this analysis we figured out that in limited range of 100 meters it is useless to increase the number of macroENB sites because of higher frequency of handover.

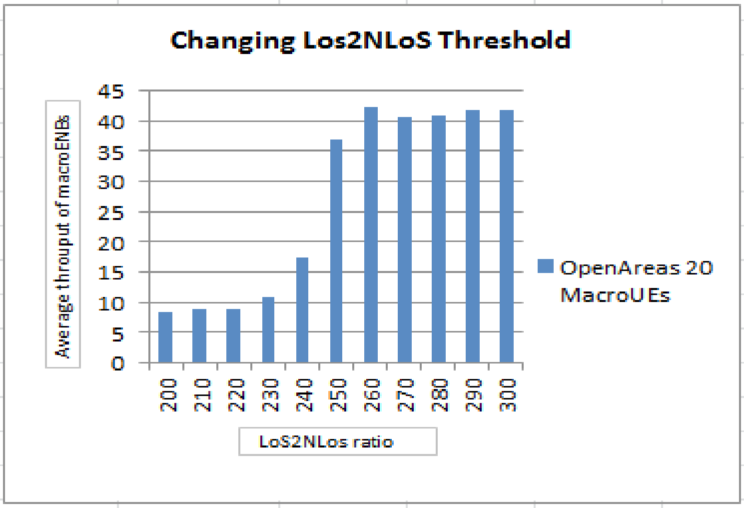

Figure 2: Changing LoS2NLoS threshold from 200 to 300 m

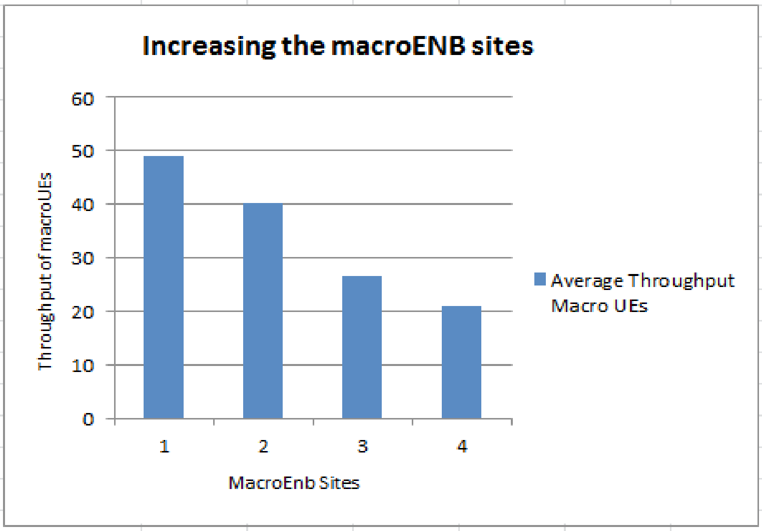

Figure 3: Increasing the number of macroENB sites from 1 to 4

C Impact of Internal Wall Loss of different materials on throughput of homeUEs

For this experiment; under our simulation settings we allocated our homeUEs in random rooms and homeUEs per homeENB ratio 2. We took different material into consideration for this analysis in our simulation as shown in Table 4. We found decreasing trend in average throughput of homeUEs that is obvious effect of attenuation in signal as seems in Figure 4; so throughput also depends on the material of building structure.

D Impact of homeUEs per homeENBs ratio on average throughput of homeUEs

For this experiment, under our simulation settings, we allocated our homeUEs in random rooms and increased the homeUEs per homeENBs ratio from 0.5 to 2 as shown in Figure 5. We found decreasing trend in average throughput of homeUEs; and it seemed to be obvious because gradual increase in number of homeUEs per homeENBs decreases the average throughput as burden increases on homeENBs; the second reason of this decreasing trend in average throughput is that for constant number of homeUEs if we varied the homeUE to homeENBs ratio, we experienced the change in average throughput of homeUEs. A higher homeUE to homeENBs ratio implies less probability of homeENBs and homeUEs to be in close proximity of each other so higher propagation loss introduced; hence in this analysis we can analyzed that the optimal ratio should be adjusted for simulation otherwise we have to face the decrease in average throughput as penalty.

Table 4. List of materials to analyze internal wall loss

Material	Thickness	Wall loss (db)
Glass	13 mm	2
Lumber	76 mm	2.8
Brick	267 mm	7
Reinforced Concrete	89 mm	27
Concrete	305 mm	35

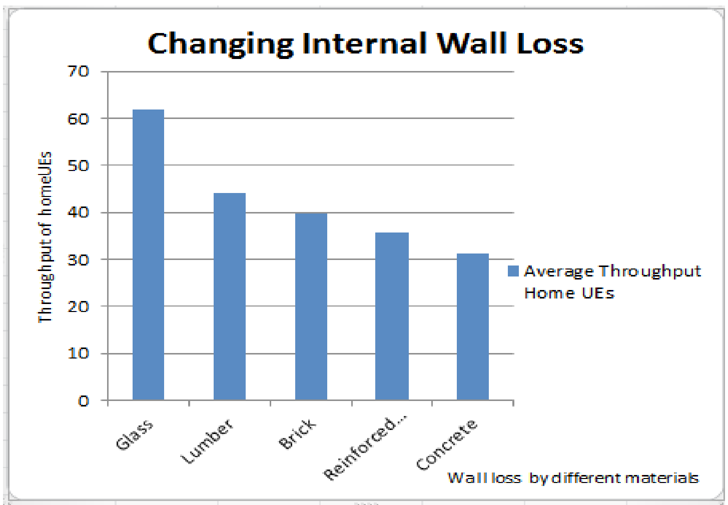

Figure 4: Changing Internal Wall Loss (db.) for different materials

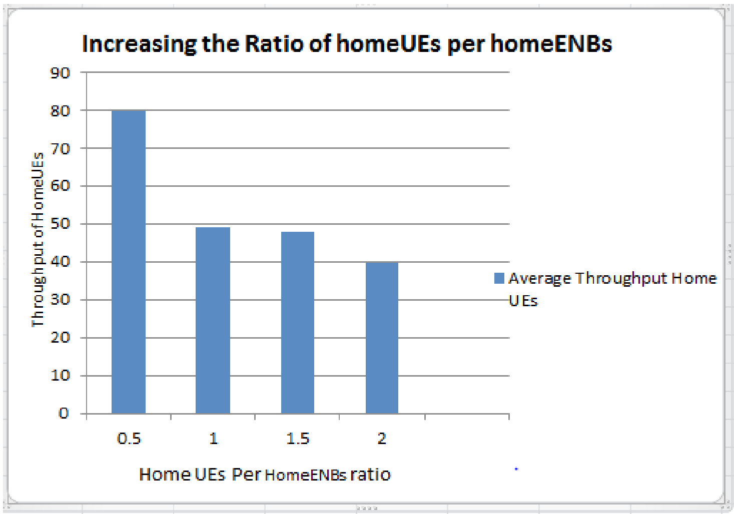

Figure 5: Increasing the ratio of homeUEs per HomeENBs from 0.5 to 2

7 Conclusion and Future Work

The overall motive of this study was to optimize the Quality of Service (QoS) of building surveillance networks based on Aerial UAVs by analyzing the effects on data throughput using realistic mobility and propagation models to mimic real world UAV based frameworks. In this paper we tried to highlight some important aspects in this area. As future work, we will consider the performance of different types of encoded video streaming by analyzing the average Picture Signal to Noise Ratio (PSNR) to maximize the end user Quality of Experience (QoE) for video viewing.[12].

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