2018 3rd International Electrical Engineering Conference (IEEC 2018)
Feb, 2018 at IEP Centre, Karachi, Pakistan

Video Stream Transmission over Network on board UAVs for Surveillance Applications

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Abstract: Nobody can deny the importance of technology in modern times to ensure proper surveillance. In recent days, voluminous attention gained by unmanned aerial vehicles (UAVs) to achieve this objective. The economical and optimize solution provided by UAVs for continuous surveillance through video at distant sites in rural and urban regions are great source of convenience where otherwise a lot of human resource and technological equipment's are needed. In this paper we proposed a framework that is UAV based which serves as an active monitoring scheme for disaster prevention or crime by taking timely action if required. Using models of wireless propagation, multipath propagation loss and shadowing, we examined the performance of mobile and stationary camera mounted UAVs in terms of throughput of such a video streaming system in a simulated environment.

Keywords: Remote video Real time Surveillance, UAVs, Wireless Propagation, QoS of UAVs

I. INTRODUCTION

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

There are several vantage points that are exists in indoor and outdoor of such sites whose surveillance is supposed to be carried out. We suggest a two tiered design for closed circuit aerial monitoring for that kind of scenario. For this work we use Wireless 4G LTE technology based on cellular infrastructure (Figure1). For real time video streaming, several indoor and outdoor cells are consists 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 homeUEs responsible for the transmission of real time video to their relevant base stations called homeENBs. In the similar way outdoor framework consists of outdoor macrocells where UAVs are flying constantly, referred to as macroUEs whom duty is to convey video in real time to their corresponding base stations mentioned as macroENBs. For Enhanced Node we use the word ENB whereas for User Equipment we use the term UE.

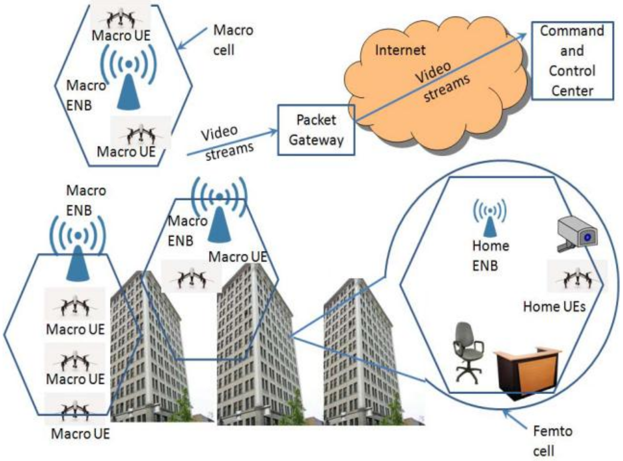

Figure1. Two tiered Building Surveillance System comprising of both Macro and Femto Cells

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 suggest 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

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 operate models supported flight patterns of UAV. To accomplish this we take 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 use Network Simulator-3 (version 3.26) to endorsed our work by simulating our experiments [3].

II. 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 [6] have considered the Airborne Networks nodes placement as a quadratic unconstrained binary optimization problem for maximum network connectivity; Though in their study UAVs are serves 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 do not focus the placement of nodes on the ground and suppose 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 does not concentrate propagation model in his research. We tried in this paper to explore some of the unanswered issues of the performance of routing performance and real propagation models using a simulated environment in NS3.

III. 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 corresponding to a deterministic model differs as per distance. We have used Friis propagation model under Line of Sight (LoS) signal propagation shown in Equation 1.

If we are talking about shadowing loss, it is the phenomenon when wireless signal has to go through hurdles (for instance walls); this condition appearance that 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 looks discontinuous reception of LoS signals and reflected forms of signals from additional hurdles. Here we are interested in to investigate the effects of shadowing loss in our infrastructure.

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

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

P_t = Transmit power

$G_t G_r$ = Transmit and Receive Antenna Gains

Equation 1: Friis Propagation Model

A. Shadowing Loss

The indoor wireless propagation model included in ns-3 includes Hybrid Buildings Propagation model. This model combines Hata model, COST231, ITU-R P.1411 model (short range communications) and ITU-R P.1238 (indoor communications) model to evaluate the path loss under different scenarios. The parameters used to model shadowing loss are depicted in Table 1.

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[9]. Under different setups we use 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 introduced any variation in the simulation settings for any specific experiment we mentioned that explicitly in its experimental results in this paper.

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

Table1. Building Propagation Model Parameters

IV. Gauss Markov - Mobility Model for macroUEs

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 used 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.

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

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

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

Equation 2, 3, 4: for Pitch, Direction and Speed

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

TIME STEP	0.5 SECONDS
ALPHA	0.85
MEAN VELOCITY	VARIABLE 1-10 M/S
MEAN DIRECTION	UNIFORM RV (MIN=0, MAX=6.28)
MEAN PITCH	UNIFORM RV (MIN=0.05, MAX=0.05)
NORMAL VELOCITY	GAUSSIAN RV (MEAN=0, VARIANCE=0, BOUND=0)
NORMAL DIRECTION	GAUSSIAN RV (MEAN=0, VAR=0.2, BOUND=0.4)
NORMAL PITCH	GAUSSIAN RV(MEAN=0, VAR =0.02, BOUND=0.04)

Table2. Gauss Markov Model Parameters to simulate mobility of macroUEs

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

In contrast the homeUEs are assumed to be stationary in this work which means either these are miniature UAVs chooses 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. HomeUEs are connected with their base stations or access points that we referred as homeENBs. Inside the building remote host connectivity is established by an internet link over a protected and secure channel.

V. 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 below in Table 3.

VI. Performance Evaluation

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

For the simulations we use Evalvid Client-Server application developed by GERCOM Group for ns3[10]. Using this application the MPEG-4 encoded video is used for surveillance recordings of the buildings.

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

ROOMS/APARTMENTS	4
Number of FLOORS	4
Number of FEMTOCELLS	2-8
Number of MACROENB SITES	1-4
AREA MARGIN FACTOR	0.5
MACROUE DENSITY (NUMBER PER SQ METER)	0.00002
HOMEENB DEPLOYMENT RATIO	0.2
HOMEENB ACTIVATION RATIO	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

Table3. Simulation parameters as per 3GPP R4-092042 specification

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

For this experiment, we simulate 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 analyzed. All the parameters are same as given in Table 3 except the values of LoS2NLoS threshold which we gradually increase for this simulation.

B. Impact of number of macroENB sites on throughput of macroUEs

By configuration in the settings of our simulation, we keep the maximum velocity of macroUEs constant i.e.2m/s; increasing the number of macroENB sites decreases the average throughput of macroUEs as shown in the Figure 3, the reason behind this decrease is handover among macroENB sites; as in limited distance of 500 meters we are increasing the number of macroENB sites, the faster switching of macroUEs occurs in handover from one macroENB site to another, result in decrease in overall macroUEs throughput.

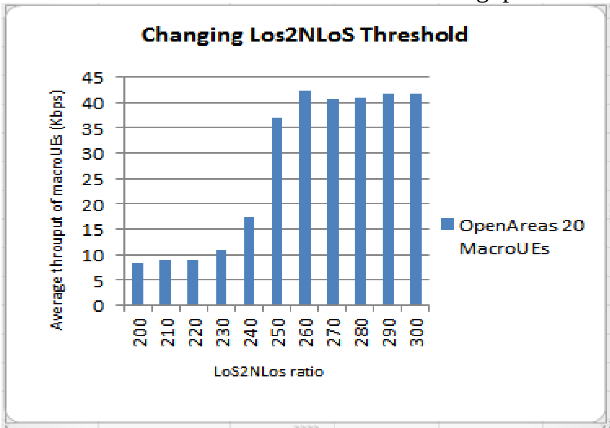

Figure2 Changing LoS2NLoS threshold from 200 to 300 m

So with this analysis we can figure out that in limited range of 100 meters it is useless to increase in number of macroENB sites because of higher frequency of handover.

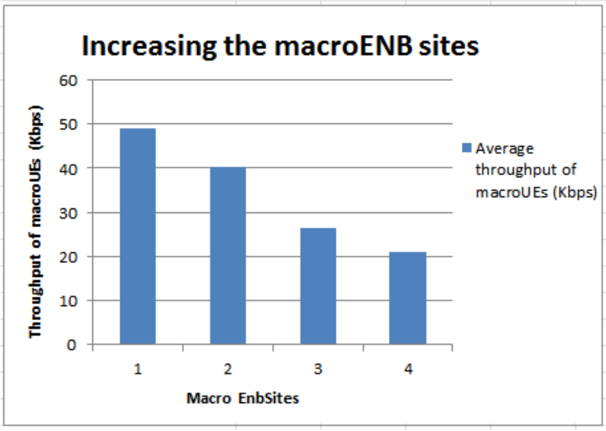

Figure3. Increasing the number of macroENB sites from 1 to 4

C. Impact of Internal Wall Loss of Different Materials on Throughput of HomeUEs

For this experiment; under our simulation settings we allocate 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.

.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

Table4. List of materials to analyze internal wall loss1

We found decreasing trend in average throughput of homeUEs that is obvious effect of attenuation in sign al as seems in Figure 4; so throughput also depends on the material of building structure.

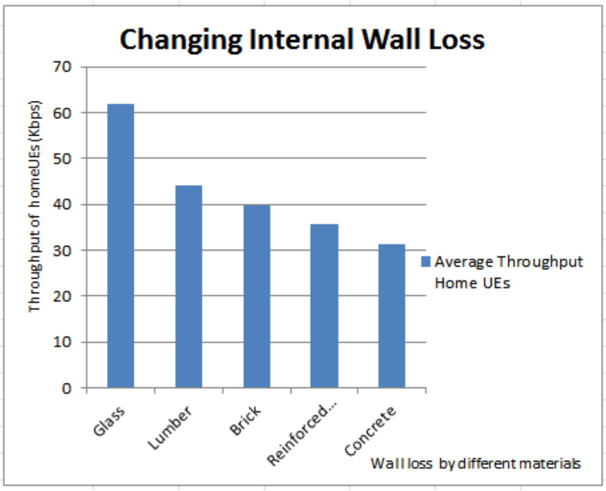

Figure4. Changing Internal Wall Loss (db.) for different materials

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

For this experiment, under our simulation settings, we allocate our homeUEs in random rooms and increase 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 seems to be obvious because gradual increase in number of homeUEs per homeENBs will decrease 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 vary the homeUE to homeENBs ratio, we experience 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 would be introduced; hence in this analysis we can understand the optimal ratio should be adjust for simulation otherwise we have to face the decrease in average throughput in penalty.

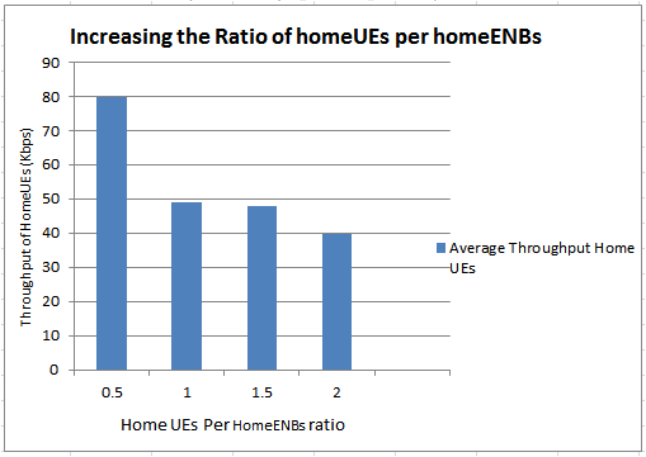

Figure5. Increasing the ratio of homeUEs per HomeENBs from 0.5 to 2

VII. CONCLUSION AND FUTURE WORK

The overall motive of this study is 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 can 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.[11].

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