13

Public Safety Applications over WiMAX Ad-Hoc Networks

Jun Huang[1], Botao Zhu[1] and Funmiayo Lawal[2]
[1]*Jiangsu University,*
[2]*University of Ottawa,*
[1]*China*
[2]*Canada*

1. Introductions

1.1 Special needs of public safety communications

Wireless communications in the public safety heavily depends on the robustness, reliability, availability and usability of the communication system. In the past decades this was achieved at the price of extremely high system cost, and was often based on specialized solution that lacked interoperability. Faced by severe cost constraints, the need to ensure interoperation of various agencies, and the desire to involve existing infrastructures available, the public safety community is increasingly attracted by the opportunity to utilize off-the-shelf technology in conjunction with both specialized and commercial communication systems.

The most basic communication need of the public safety is radio-based voice communications. This type of communication allows dispatchers to direct personnel to areas where incidents have occurred. The trend in this marketplace has been geared towards allowing for inter-agency communication in case of large-scale disasters. The most notable large-scale response effort occurred on September 11, 2001, when multiple agencies responded to the attacks in New York. The state of the most basic radio technology could not meet the increasing demand for radio communications that arose on that day. The crush of radio communications flooded the spectrum, and caused massive failures across the board with regard to the base station relaying of crucial information, led to more deaths of first responders. The most gripping issue regarding the state of the technology at that time was the fact that the same failures had occurred in 1993 and nothing had been done to address the issue. More focus had been put on developing faster and more lucrative consumer market, and the mainstream vendors had forgot this niche space.

Radio was the primary medium for the transmission of voice communications. Later developments allowed for the transmission of voice and data over the same radio spectrum. The problem was that the only people capable of receiving these transmissions were other first responders in the same department. There was an inability to communicate across different departments or agencies for coordination during a disaster. The conventional radio system typically had three segregated channels: car to station, station to car and car to car.

There was also a shortfall due to the fact that personnel must wait for a transmission to complete prior to being able to send their own transmissions, since the channel only allowed for one speaker at a time. A vehicular mesh network would have allowed for additional channel resources for voice communication. Further, a video channel could have been set up with real-time situational awareness, with a tie in to vehicle or body cameras. Short message service through the use of private messaging networks would also have been available in the event that a voice channel was unavailable, thus allowing for vital information to be relayed immediately rather than waiting for a chance to transmit. P25 group is addressing this issue for voice and data; here we focus more on video on-the-go.

When a fireman trying to rescue a people, the environment is harsh and noisy, some times voice is not that effective and live video or GPS (Global Positioning System) data is needed to assist the coordination's. The camera is normally mounted on firemen's helmet, and wirelessly transmitted to the fire-engines (service vehicles) on the spot, for the commander to see how are every team members doing; the goal is to keep firemen alive at the first place, and then to rescue as many people as possible. Comparing with voice or GPS and other sensor data such as temperature, CO density etc, video data is relative large and harder to get through wireless channel, however "a picture may worth a thousand words"; for this reason we focus on the evaluating video over Vehicular Ad-hoc Network (VANET) in this study.

Fig.1.1 shows video communication application of the techniques disclosed herein, for public safety authority usage. The system includes a national control centre at the gateway level, a police car and a fire engine incorporating mobile servers at the service truck level, and mobile terminals which are carried by public safety personnel. The terminals gather information which being transmitted to the servers and then on to the national control centre for subsequent access by client systems.

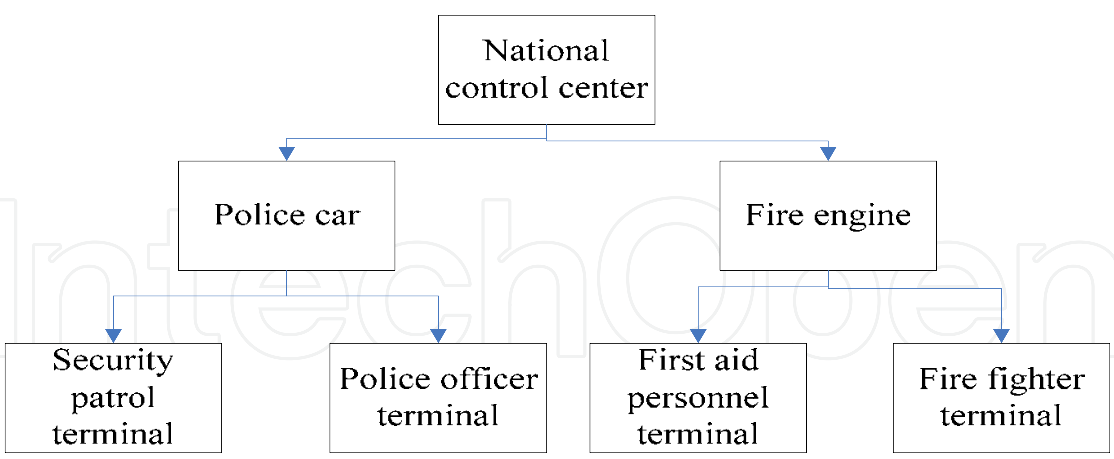


Fig. 1.1. A system architecture of public safety communications

Fig.1.2 is a typical Point-to-Multi-Point (PMP)/ Multi-Point-to-Point (MPP) and Peer-to-Peer (P2P) JXTA network, including fixed client systems operatively coupled to a gateway through a communication network. The gateway is operatively coupled to a mobile server through a satellite system, and also to a remote server. The mobile server is operatively coupled to mobile communication devices, including a mobile client system and mobile terminals. The remote server is operatively coupled to remote terminals.

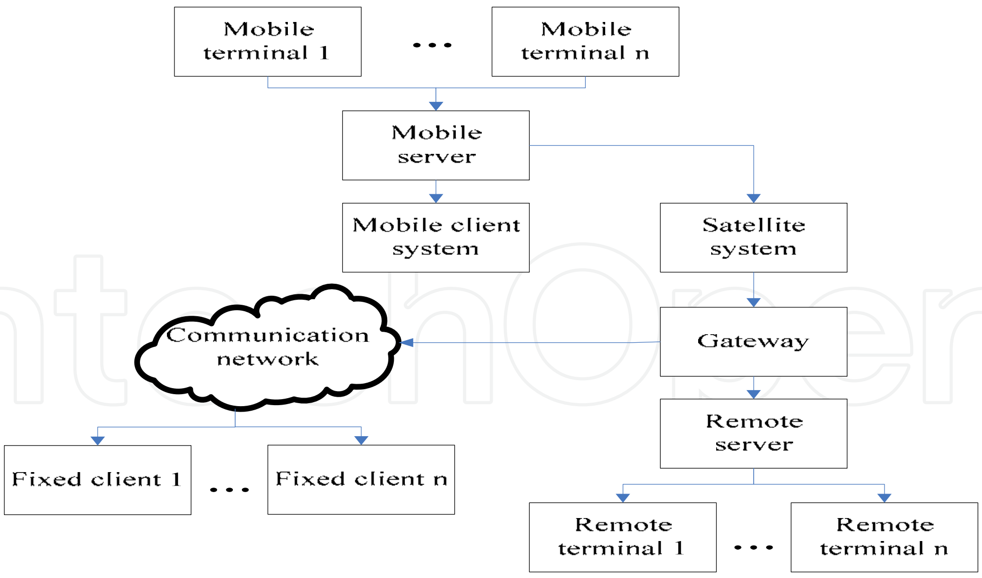


Fig. 1.2. PMP/MPP/P2P public safety networks

Note that any thing mobile must go through wireless here. Software defined radio is used to bridge the gaps, between each section of the network, while they are moved around.

Fig. 1.3. Public safety system road test scenes

Above are the streets views where communications between our mobile server and mobile client were interrupted for more than 20% of time, where end-to-end delay exceeded more than 10 seconds at the peaks, during the frequency and network switching. Those field tests have partially trigged our in depth studying.

1.2 Vehicular networks for road safety

Vehicle to vehicle communication needs a unique Ad-hoc communication scheme that is self-organizing, and it can function without a pre-existing cellular infrastructure network. This is an essential feature of VANET because when conventional communication towers are suffering outages or become non-existent, Ad-hoc communication can provide an effective way to transmit information. Due to the rapidly changing topology and the speed of the vehicles in Ad-hoc network, a number of issues become increasingly important to ensure the efficiency and stability of this network. Here we focus on the video traffic sizing challenge, which is the key to unlock the power of video applications. Like every other wireless environment, transmitting video signals in a VANET poses concerns. Handling congestion and packet loss becomes more difficult and delicate in a VANET environment where interference is inevitable. Interference such as electromagnetic waves from starting car engines with electronics, from Additive White Gaussian Noise (AWGN) wireless channel under critical weather conditions, can all affect the Quality of Service (QoS) as seen by the end user. The topology is constantly changing and vehicles could move out of sight from one another causing an outage in video transmission.

In addition, unlike every other network environment, VANET mobility has a peculiar and unique nature due to the randomness of human behaviour. In creating an effective mobility model, vehicle-to-vehicle interaction and vehicle to infrastructure interaction needs to be considered carefully and closely. One of the major research issues in VANET is the creation of an effective simulation platform that can integrate a network simulator with a realistic vehicular traffic simulation model. According to (Sommer & Dressler, 2008), the effect of having a realistic mobility model is evident. In integrating a network model with a VANET mobility model, two approaches are identified: an open-loop integration approach and a closed-loop integration approach. The latter entails integrating traces generated from a mobility simulator to a network simulator while the former runs the two simulators concurrently. In other words, in the closed-loop approach, the traffic simulator and the external VANET mobility simulator are connected using High Level Architecture (HLA) design for distributed computer simulation systems, so that the two components feed the most recent information back to each other. The closed-loop approach is more effective as it allows the effect of the wireless signals to govern the mobility patterns of drivers. It also models driver reactions to certain wireless signals as detailed in (Sommer & Dressler, 2008).

1.3 WiMAX made for VANET

WiMAX (WiMa, 2009) is a 4G equivalent technology standardized by IEEE802.16 that enables the delivery of last mile wireless broadband access. The name WiMAX was created by the WiMAX forum, which was formed in June of 2001 to promote conformity and interoperability of the standard (Brit, 2010). The WiMAX technology (Ghosh, 2007) provides ease deployment as it eliminates the use of cables and can save investment when used in remote and rural areas. The technology is scalable and has a flexible frequency re-use scheme because it can use Orthogonal Frequency Division Multiplexing (OFDM) technology. WiMAX implements full Multiple-Input and Multiple-Output (MIMO) setting, which is a good fit for mobile and car applications, by enhancing timely information delivery to save lives and improve quality of life.

A comparison of these physical layer technologies that could be used for VANET is shown in Table1.1 (Morgan, 2010). The '$$' in the table was used to denote the cost per bit for each technology where '$' represents the least expensive and '$$$$' represents the most expensive. Through comparison, one can see that WiMAX is the most cost effective approach by providing a data rate that can satisfy the needs of our mobile multimedia users (low latency and high coverage) at high speed and at an affordable cost.

One of the major challenges in VANET design is the development of an effective platform that can bring all issues described earlier under one umbrella – a complete simulation model. Since it is safer and more cost efficient to simulate possible solutions rather than field experimenting of driving at 140km/hr, creating an effective VANET simulation platform

Items	*WiMAX*	*Satellite*	*DSRC*	*FM Radio*	*GSM*	*CDMA*
Max Range km	<50	1000s	< 1	100s	<10	<10
Data Rate mbps	70	100	10	0.01	0.1	2
Cost per bit	$$	$$$$	$	$	$$$	$$$
Average Latency	Lo	Lo	Very Lo	Hi	Lo	Lo
Connectivity	Hi	Very Hi	Lo	Lo	Hi	Very Hi
Sustain km/hr	180	100	80	120	140	110

Table 1.1. Comparison of related wireless technologies for video on the go application

has become of pertinent importance in research and industry. One of the major challenges faced is integrating an effective mobility model that puts vehicle to vehicle interaction and vehicle to infrastructure interaction into consideration, along with platform possessing the full functionalities of a communication device with effective receiving, processing and transmitting capabilities, thus emulating a real world situation. Human behavioural modelling are also some of the other issues to be modelled as close to reality as possible, to produce conclusions that can be used in the real world. Although (Wegener et al., 2008) have worked on creating a similar platform, no specific work have been done using OPNET as a popular network simulation tool. In addition, customizing the platform for real-time video traffic is a specific area we explored using different traffic level scenarios.

1.4 WiMAX Ad-hoc network

WiMAX is a broadband wireless technology that can sustain voice, video and data services at high moving speed while maintaining high data rates. Mobile WiMAX is based of OFDMA physical layer of the 802.16e-2005 standard, which is a revision of the fixed WiMAX standard. IEEE 802.16e provides functionalities such as BS handoffs, MIMO transmit/receive diversity, and scalable Fast Fourier Transform sizes (Li, 2006). WiMAX is considered one of the most promising technologies in the rural area today. Ad-hoc network (Song & Oliver, 2004) has emerged, for instance, wireless mesh network, and it rapidly gained acceptance and interest from both academic and industrial communities for the advantages of low up-front cost, easy network maintenance, good robustness, usability, reliable service and larger coverage. Thus, the mesh mode was defined in the IEEE 802.16 standard as an additional architecture to the previous Point to Multi-Point (PMP) mode. In the PMP mode, nodes are organized into a cellular like structure consisting of a Base Station (BS) and some Subscriber Stations (SS). All the SSs must be within the transmission range of the BS, and traffic only occurs directly between BS and SS. Mesh SS communication without going through the Mesh BS, network traffic can through other Mesh SS, two Mesh SS communicate in direct. Comparing with PMP mode, the mesh mode can provide better coverage, survivability, flexibility and scalability, thus a great deal of research works have been done focusing on WiMAX (Zhou & Ji, 2010) mesh networks for performance improvement. Many of the works concentrated on the construction of routing trees (Chen et al., 2008) and link or packet scheduling with spatial reuse, aiming to maximize the throughput, maximize the number of concurrent transmission links, minimize the end-to-end delay, and provide better fairness. The Ad-hoc mode of VANET for public safety is a special mesh mode; the focus is more on survivability and usability rather than increased bandwidth.

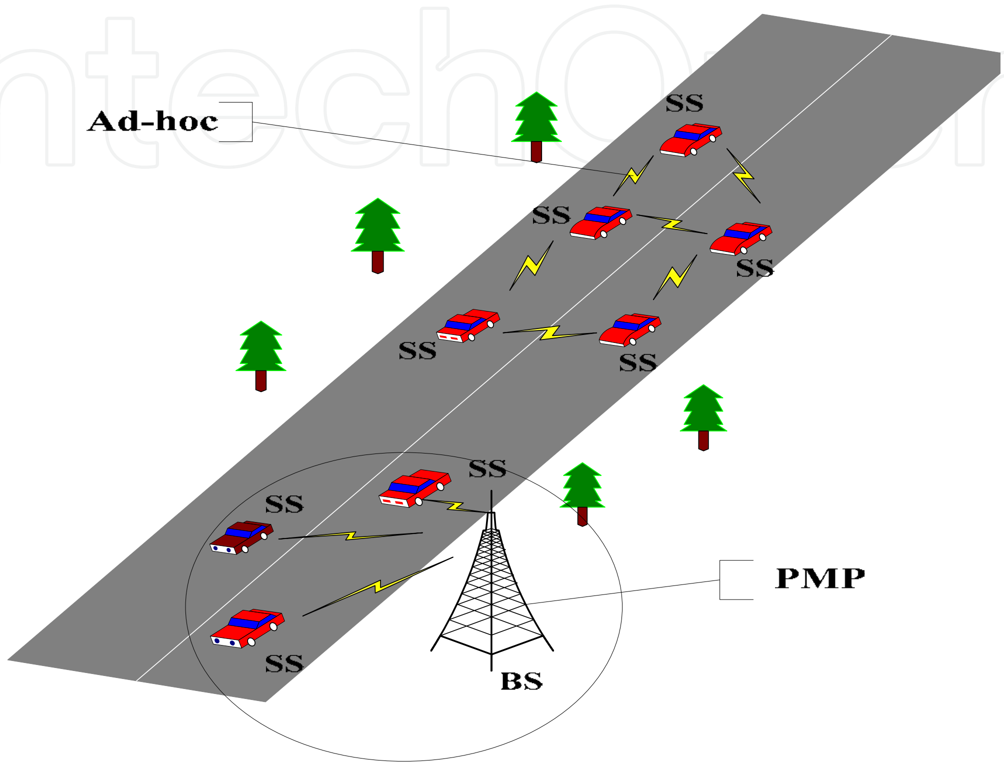


Fig. 1.4. WiMAX Ad-hoc vehicle networks

2. Public safety networks operation, models and assumptions

2.1 Safety network operation

This section describes the network layout of VANET with WiMAX technology along with their operation that are of interest to this research.

2.1.1 General network layout of VANET

In the VANET we envisioned, each vehicle has the ability to communicate with any neighbouring vehicles. Depending on the nature of the message, the information either remains within the VANET or venture out to the backhaul network via the Road Side Unit (RSU). For instance, brake warning sent from preceding cars, tailgate and collision warnings are messages that can remain in the VANET network. In the sensor application (Li et al, 2009), video messages are forwarded from the point of interest (which could be a traffic congestion area, camera view from unmanned car, road block, accident scene etc), to the backhaul network via the RSU to aid traffic personals, emergency agents or any other party to respond to such situations more effectively.

To study the traffics generated within the network, we consider a VANET consisting of N cars communicating with each other and with the Internet via RSUs. The network topology is shown in Fig.2.1. The RSU (BS1 or BS2) has the capability to handle up to 100 cars simultaneously. Each car is associated with the RSU depending on their distance to one another. The video packets are routed and given priority due to the service class name associated with them and the scheduling type, which handles the bandwidth request/grant mechanism. The silver service class and the Real-time Polling Service (RTPS) scheduling are used. Maximum sustainable traffic and reserved traffic rates are set to 384kbps for this service class. The minimum rate between cars is set to 96kbps.

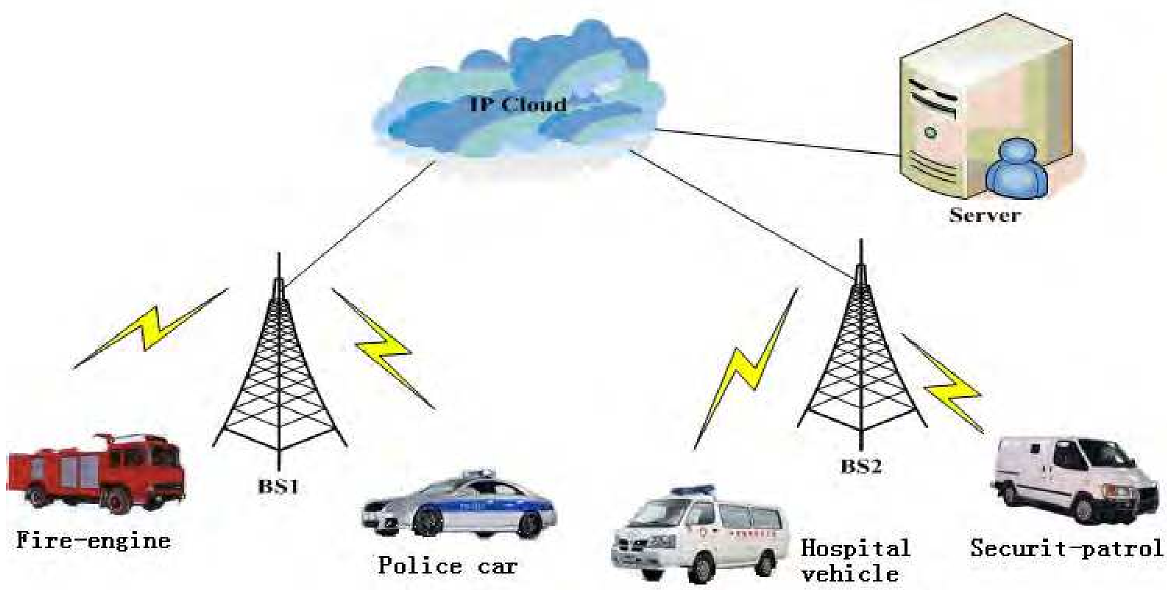


Fig. 2.1. Public safety network topology model

At the SS station, over the low sub-layer Air Interface, the average Service Data Unit (SDU) size is less than 768 bytes, such that the entire packet can survive the wireless transmission. The larger packet is very vulnerable to interference of all kinds. Each video arriving from the higher layer is expected to be broken down to this size range. Any packet size greater than this shall be segmented before encapsulated into a Protocol Data Unit (PDU) and transmitted with appropriate header information, any packet less than this shall be merged with previous leftover or next small packet if possible before encapsulated for Air Interface. When a SS wants to transmit video, the video is generated from the application layer using our traffic generation model. The packet is sent to the RSU and the RSU forwards the packet accordingly. The IP cloud is set to its default values and acts as a router. The server is configured to accept packets generated by our model.

WiMAX is known for its data rates up to 128Mbps downlink and 56Mbps uplink using its MIMO antenna techniques. In our case, we used Simple Input Simple Output (SISO) antenna technique, which supports up to 1Mbps uplink and downlink. It defines service flows that can be mapped into gradual IP sessions to enable end-to-end IP based QoS. Scalability, Security and mobility management are the other major features of WiMAX technology.

In our OPNET model, WiMAX does not support network-assisted handover, base station-initiate periodic ranging and power management. A sub-channel is allocated to each user thereby reducing the channel interference in the frequency domain. OFDMA is the scheme used allowing multiple accesses to every user on our network. At the Network layer, IPv4 is used for addressing and Routing Information Protocol (RIP) is used as the routing protocol. RTSP is a real-time streaming protocol designed for streaming video.

2.2 Public safety network models and assumptions

2.2.1 VANET Video model

Fig.2.2 shows a diagram summarizing the various components of our model. The video VANET OPNET model, consist mainly of the Video model and the VANET model. By first analyzing a live video trace, characterizing the trace and modeling the characterized trace then feed it into our simulator, to obtain the final Video model. On the other hand, the VANET model consists of the VANET mobility model and a communication model.

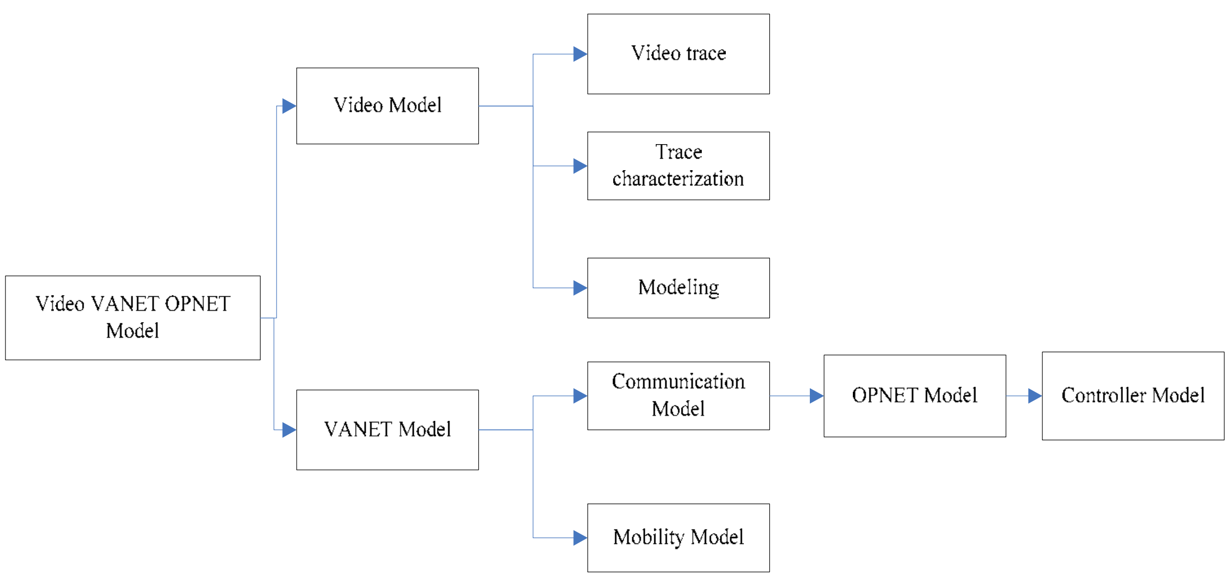


Fig. 2.2. Video VANET OPNET model tree structure

OPNET modeller provided the platform for the communication model and allowed for the integration of the various components of the Video VANET OPNET model.

a. VANET model

From our survey, Table 2.1 shows a summary of the findings.

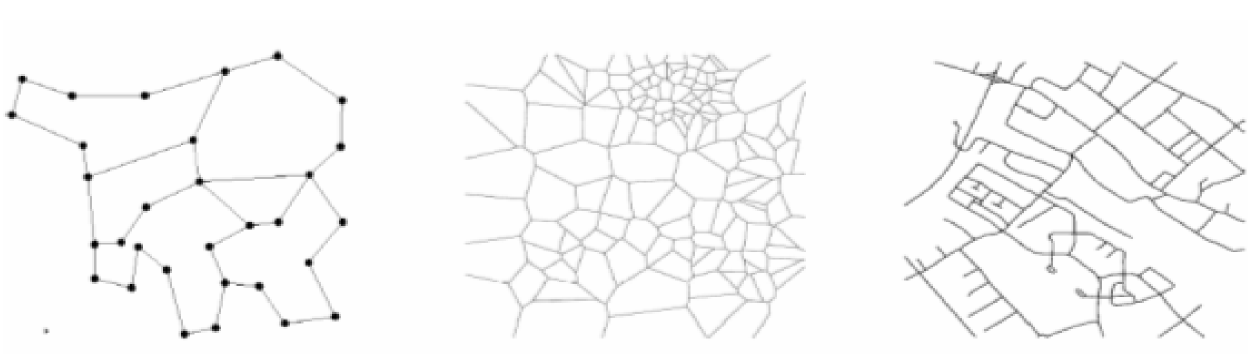
The result of this analysis presents VanetMobiSim as the only mobility model found as of the time of development that could be integrated into OPNET consequently influencing our choice. VanetMobiSim's ability to integrate into OPNET comes with its flexible to manipulate its output file by coding its output generator file to produce a desired format.

Besides its adaptable output abilities, VanetMobiSim incorporates both microscopic and macroscopic models to allow the modelling of vehicle-to-vehicle and vehicle-to-infrastructure interaction. Traffic light integration, stop signs, human mobility dynamics

Items	*OPNET*	*ns2*	*QualNet*
MoVES	No	No	No
STRAW	No	No	No
VanetMobiSim	Yes	Yes	Yes
SUMO	No	Yes	Yes
SHIFT	No	No	No
GMSF	No	Yes	Yes

Table 2.1. Mobility model summaries

and safe inter-distance management are all modeled in this tool. The different forms of topology are shown in Fig.2.3 (Fiore et al., 2007). VanetMobiSim provides a flexible platform in which the user can configure the path used during a trip between Dijkstra shortest-path, road-speed shortest path and a density–based shortest path. The trip could either be generated by random source-destination or activity-based (Fiore et al., 2007).



a) User- defined topology b) Randomly defined topology c) GDF map topology

Fig. 2.3. Typical mobility topologies

The RSU and car communication are the major communication nodes in VANET. Our RSU is a simplified WiMAX BS. Each car is equipped with proper communication tools to enable car to car and car to infrastructure (RSU in our case) interaction. The design of each RSU is robust and non-application sensitive so that every car can send and receive a wide range of information. Table 2.2 shows the basic essential characteristics of our model along with some typical settings.

Parameter	*Value*
Physical layer	IEEE 802.16e
BS TX power (W)	5
Number of TX	SISO
BS Antenna Gain (dBi)	15
Minimum Power Density (dBm/Hz)	-80
Maximum Power Density (dBm/Hz)	-30
Link bandwidth (MHz)	20
Base Frequency (GHz)	5.8
Physical layer Profile	OFDM

Table 2.2. Typical RSU parameters

b. IEEE802.16 video model

The video model is one of the main components of our VANET OPNET model as our research focuses on real-time video communication in a VANET environment. In creating our video model, we put certain factors into consideration to measure the usefulness of the model. According to (Huang, 2001) factors like parsimony, analytic correctness, flexibility, implement ability and absolute accuracy was considered with MOS (Mean Opinion Score) method, on a scale of 1 to 3, using the factors mentioned above, 1 being the least and 3 the greatest. As common sense, each model has its pros and cons. With respect to our application, we choose parsimony and implement ability as our highest priorities.

Items	*Mini Pareto*	*FBM*	*TCP*
Parsimony	2	3	1
Analytical	2	1	1
Flexibility	1	1	1
Implemental	3	2	1
Accuracy	2	2	3

Table 2.3. Traffic model methodology comparisons

Table 2.3 shows other models and their MOS rating with respect to the factors described above. We have taken a systematic approach in developing our mini-Pareto model. Video traffic trace was collected using the same camera used for a car-to-car road test. The traces were analyzed and stochastically represented and plugged into our simulation platform.

2.2.2 Modeling assumptions

Unless otherwise stated, the following are assumptions taken throughout the chapter:

1. Every vehicle in the network is equipped with necessary radio. Every vehicle on the road has the capability to receive from and send video data to other vehicles via the RSUs.
2. BS is a "stationary" node. This is required due to the limitation of our OPNET model and we need it to act as an intermediate node for packet forwarding to the destination.
3. No disruption in a communication channel because one can use dedicated channel allocation once the node is in the communication range of a RSU.
4. Finite buffer size for each transmitter: this is a more realistic assumption, which would also allow us to find the trade-off between buffer size and end-to-end delay.
5. The RSU use OFDMA for multiplexing and their is always a slot available for each SS sending video traffic, Media Access Control (MAC) layer stress test will be studied later.

3. Laboratory set-up and trace collection

This section presents the experimental set-up of our model. It discusses the trace collection process and the initial analysis done on the trace. The later sections then describe the simulation environment, scenarios and performance measures used in this work.

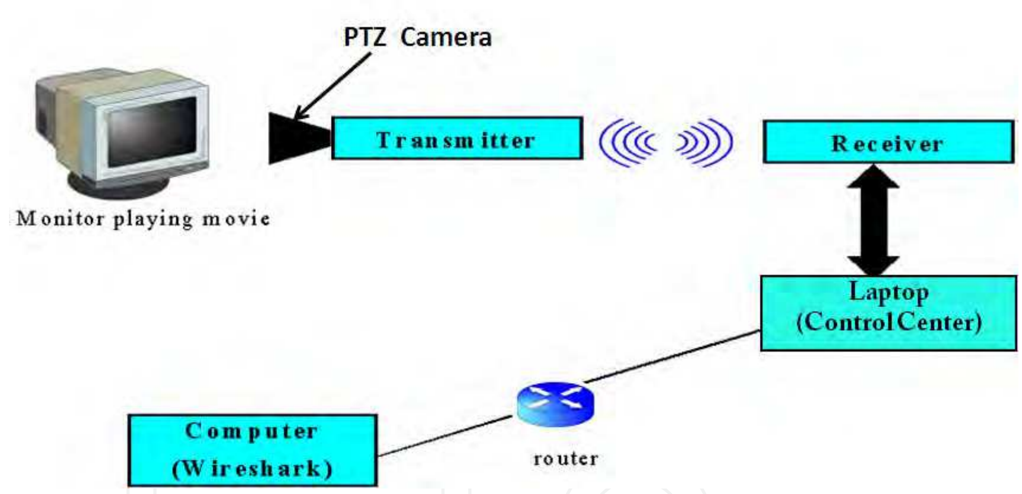


Fig. 3.1. Set-up for taking wireless video traces

3.1 Experimental conditions

We need to first collect video traces in order to model a video characteristic that is as close to reality as possible. Traces from a live camera were obtained using WireShark software on a monitoring PC. The set-up is shown in Fig.3.1. The monitor was used to play a series of video clips for 10 minutes each. The transmitter sends the compressed (in a ratio of 250:1) and encrypted video images to the control centre via a car-to-car radio system. The receiver decodes and decompresses the received video frames and plays the image at the control centre at about 20fps. The control centre laptop and the receiver are connected using a USB port. The control centre is then connected through a router to a computer hosting the packet trace-capturing tool – WireShark. Once the system is turned on, the computer with the WireShark software is set to access the "capture" folder in the control centre before streaming the video. The WireShark software is turned on and the trace capture begins. The video clips were chosen based on the activity rate in the clip. Three types of video clips are chosen and described in the following.

1. Action movies. This type of movies has a lot of movements and hence more variations in frame sizes. “The Prisoner” by Jackie Chan was chosen for study here.
2. Drama: This type of movies has an average movement and hence, it’s a mixture of frame sizes. “The Game Plan” with Dwayne Johnson was chosen for this study.
3. A romantic: This type of movies has very slow scenes hence, little or no variation in frame sizes. “28 Day“ with Sandra Bullock was chosen for this study.

3.2 Initial analysis and detail parameter matching

The next challenge was to analyse the trace and create a video traffic model. Fig.3.2 shows the schematics of our traffic model. The number of sources, N, was to be chosen bearing in mind the trade-off between parsimony and accuracy (Parsimony refers to the provision of the simplest and most frugal available solution to a certain problem). Each mini-source represents each set of video object sub-stream with the switch being regulated. The switch is configured to form traffic with a long-range dependency. We modelled the on-time switch by a Pareto distribution and the off-time by an exponential process, since we believe the memory between action sequences is negligible, but within the same Action Unit (AU), the sequences are strongly correlated (Gu & Ji, 2004).

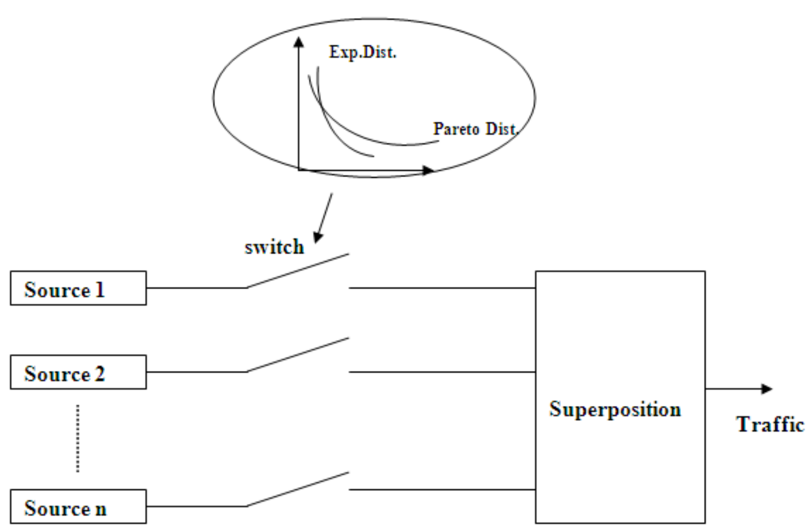


Fig. 3.2. Mini source model for video traffic generation

The problem with previous standardized 4IPP model is the matching process with Index of Dispersion for Counts (IDC) curve from measured data is complicated, especially when we need to scale up or down for different data rate and different applications. Also the distribution is tied down on the traditional exponential, lacks the flexibility to include the more general distribution such as Pareto, or Weibull on-off latterly proven has property of large deviation (Duffy & Sapozhnikov, 2007); most engineers also believed that Weibull can model wide range of WWW traffic, and Pareto is good for video. Here is a quick review of distributions used in OPNET tool:

Pareto definition:

$$f(x) = c_p \alpha_p^{c_p} / x^{c_p+1}, \ \alpha_p \le x < \infty \tag{1}$$

Mean: $E(x) = c_p \alpha_p / (c_p - 1)$, $c_p > 1$. Arg1: location = $\alpha_p > 0$, Arg 2: shape = $c_p > 0$.

Exponential definition:

$$f_x(x_o) = \begin{cases} \alpha_e e^{-\alpha_e x_o} & x_o > 0 \\ 0 & \text{otherwise} \end{cases}, \ \alpha > 0 \tag{2}$$

Mean: $E(x) = \alpha_e^{-1}$.

Weibull definition:

$$f(x) = \begin{cases} 1 - e^{-\left(\frac{x}{\beta_w}\right)^{c_w}} & x > 0 \\ 0 & \text{otherwise} \end{cases} \tag{3}$$

Arg: shape = c_w.

Lognormal definition:

$$f(x) = \int \begin{matrix} \frac{1}{x\sqrt{2\pi\sigma^2}} \exp \frac{-(\ln x - \mu)^2}{2\sigma^2} \\ \hline 0 \end{matrix}, \ \begin{matrix} \text{if} x > 0 \\ \text{otherwise} \end{matrix} \tag{4}$$

Mean period: $E(x) = e^{\mu + \sigma^2/2}$

In this new proposed baseline extension model, we have included both Pareto and Weibull distribution, which are available now in OPNET library due to our previous suggestions to the tool vendor. The detail matching steps from WireShark measurement to the OPNET parameters are offered as followings:

Here is the procedure deciding the number of mini sources (N_s).

$$N_S = 1 + \overline{R_I} / \overline{R_T} \tag{5}$$

$$R_I = P_I / T_I \tag{6}$$

$$\overline{R_T} = \overline{P} / \overline{T_I} \tag{7}$$

R_I is instant rate, $\overline{R_I}$ is average instant rate, P_I is instant packet size, $\overline{P}$ is average packet size, T_I is instant inter-arrival time, $\overline{T_I}$ is average inter-arrival time, $\overline{R_T}$ is average rate total.

We recommend 9 on-off mini sources, if you wish to skip above step; however above matching process is not limited to 9, can be more or less, depends on the trace characteristics and how accurate or how fast you want the model be, more mini sources, simulation will run slower, but relatively more accurate. Once the number of mini source is chosen, we are ready to find out the corresponding histogram from the WireShark trace of packet size.

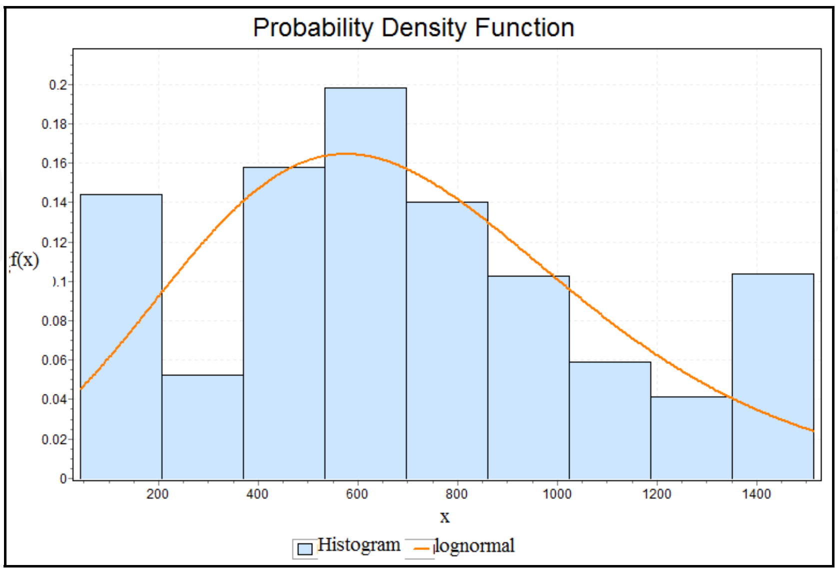


Fig. 3.3. Typical PDF of wireless video trace

Having obtained the i=9 bin pdf(i) (Fig.3.3) of the video trace calculated using a tool called EasyFit, the program decided that the lognormal distribution as the best distribution to fit the given data. The orange curve is the result automatically generated using the lognormal distribution. Matlab or Excel Macro can also be used to fulfil this task of finding the best-fit analytic curve for the histogram. Once the relative strength of each mini source is identified, we need to find out the fundamental Hurst parameter as follows:

IDC formula is defined below:

$$F(T) = \frac{E[S_T - E[S_T]]^2}{E[S_T]} = \frac{E[(S_T)^2] - E^2[S_T]}{E[S_T]}, \quad S_T = X_1 + X_2 \ldots + X_T \tag{8}$$

$$F(T) - 1 = (T/T_0)^{\lambda}, \lambda = 2H - 1, \ \lambda \in (0,1) \tag{9}$$

$$\log(F(T)-1) = (2H-1)\log(T/T_0) \tag{10}$$

We can obtain the slope λ from different points $(\log(F(T)-1), \log(T/T_0))$ on the IDC curve.

The shape parameter, c, of the Pareto distribution is related to the Hurst parameter as shown in equation (11) below. The slope of the IDC curve gives the Hurst parameter from equation (12). As shown from the curve, the fractal effect calms down, but does not disappear, for this reason we call it persistent Hurst phenomenon (Mehrvar et al., 1996).

$$H = \frac{1}{2}(3 - c) \tag{11}$$

$$H = \frac{1}{2}(1 + \lambda) \tag{12}$$

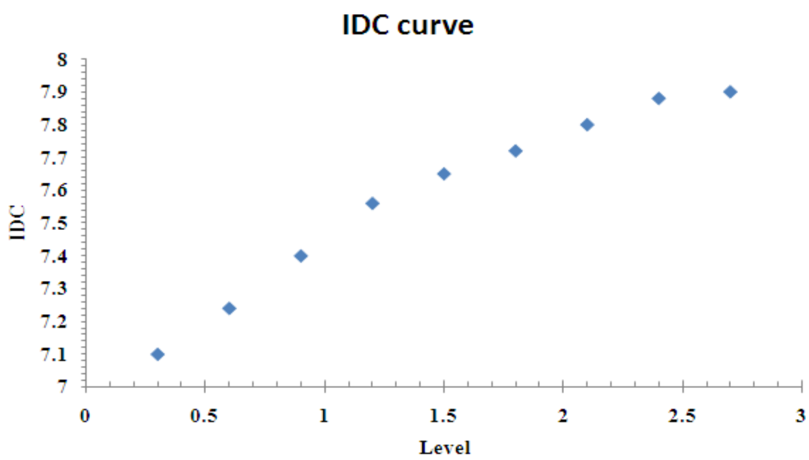


Fig. 3.4. Entire trace IDC curve

Again IDC curve can be either calculated by Matlab program or Excel Spreadsheet by calling standard deviation function recursively. When video is compressed with little loss of information; the peak to average ratio decreases. The Hurst parameter can be used to reflect this invariance phenomenon of entropy conservation property (Hong et al., 2001). Since our video is highly compressed but still preserves the original entropy of the information, we use the Hurst parameter to accurately capture this scaling invariance, modeling it with on-time distribution. On the other hand, an exponential distribution was used to model the off-time, which represents the time between each object action scene. This distribution was chosen with the observation that the action scene sequence is relatively memory less. And thus we have:

$$T_{on} = P(i) / \left(\overline{R}_T / N_s \right), \ 1 \le i \le 9 \tag{13}$$

$$\alpha_p = T_{on} * \left(C_p - 1 \right) / C_p \tag{14}$$

P(i) is the packet size for ith mini-source, $\overline{R_T}$ was calculated from WireShark trace, 46.13kbps for our case. The Pareto shape is $C_p = 1.6$, and for Weibull $C_w = C_p - 1 = 0.6$, in our situation.

Now we have on-time calculated, to obtain off-time, we need to find out the frame Correlation, the formula is below:

$$R_X(t_1, t_2) = E\{X(t_1)X(t_2)\} = \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} x_1 x_2 f(x_1, x_2, t_1, t_2) dx_1 dx_2 \tag{15}$$

$$T_{off} + T_{on} = L / pdf(i), \ 1 \le i \le 9 . \tag{16}$$

L is the Correlation Length, depends on Frame FP, which is calculated by WireShark, 54.4ms for us, $L = L_c \times FP$.

$$\int_{\tau_0}^{\infty} r_X(\tau)d\tau < 0.25, \tau = t_1 - t_2 \tag{17}$$

Correlation lags, $L_c = \tau_0 = 20$ here. Table 3.1 shows a summary of each mini Pareto source and its characterization values mapped according to above steps.

Bins	*Location (ms)*	*Packet Size P(i) (Bytes)*	*Mean Off-Time (ms)*	*Mean On-Time (ms)*	*pdf(i)*
mini1	*56*	*96*	*13450*	150	0.08
mini2	*168*	*288*	*9442*	449	0.11
mini3	*253*	*432*	*6126*	674	0.16
mini4	*365*	*624*	*5071*	973	0.18
mini5	*449*	*768*	*6056*	1198	0.15
mini6	*561*	*960*	*7570*	1497	0.12
mini7	*646*	*1104*	*10367*	1722	0.09
mini8	*758*	*1296*	*16112*	2021	0.06
mini9	*842*	*1440*	*19514*	2246	0.05

Table 3.1. Mini sources with characterization values for OPNET

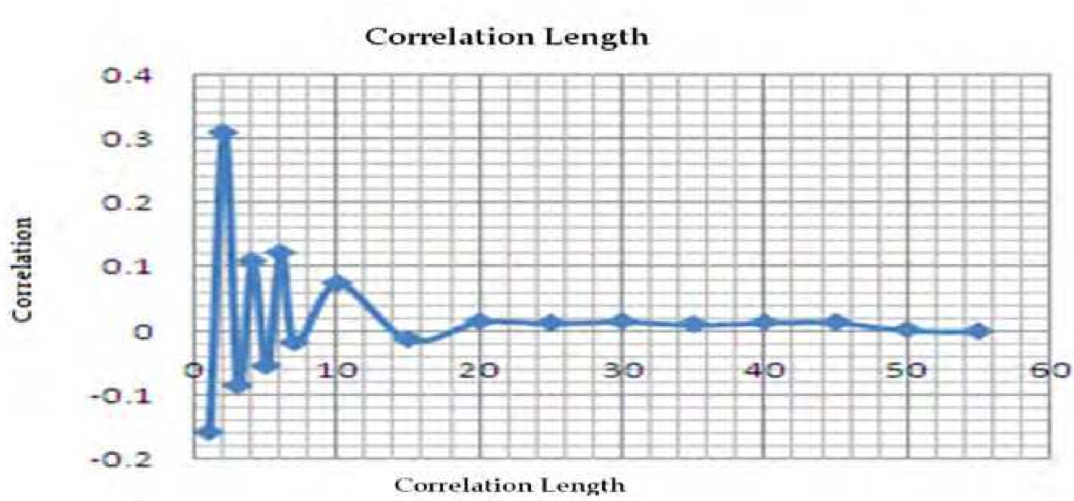


Fig. 3.5. Frame correlation length

In summary, for our Pareto mini source, the shape is obtained from IDC slope, the location is obtained from the mean value of the inter-arrival time and the shape, and finally the mean off time is derived from the correlation length of the trace and the lognormal distribution of packet size. The correlation curve is shown in Fig.3.5. Correlations show a predictive relationship in a sequence of data. Fig.3.5 shows that our frames are correlated since actions are correlated, however, as one can see, there is not much correlation beyond a length of 20 lags; consequently, our correlation length can be either visually chosen for simplicity, or go through integration of the formula (17) for a more tightly bounding. Note that curve fitting to lognormal can be skipped; we do it for the purpose of the easier scaling of the model later on, without refitting for every trace. When scaling for different video rate, all we need to do is simply set the constant bit rate of each mini source in OPNET to the desired video rate directly. More important, with the above-mentioned distributions, the mini on-off model can be readily mapped into BMAP/D/1/K queue or $M^X/G/1/PS$ queue (Feng & Misra, 2003), where we can obtain the numerical solution or analytical bound below.

$$\text{Mean(JobSojournTime)} \leq \frac{\text{Variance(Batch)} \times \text{Variance(Service)} \times \text{Load}}{\text{Mean(Batch)} \times \text{Mean(Service)} \times (1 - \text{Load})} \quad (18)$$

With our carefully matched Pareto and Lognormal distributions, the quick calculation shows that the actual delay bound could be as 69 times higher than a simple M/M/1 queue estimation.

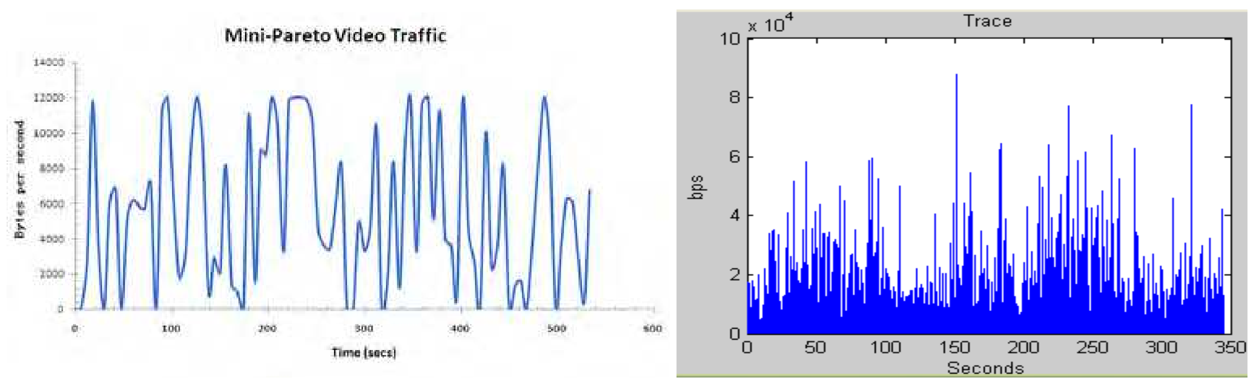


Fig. 3.6. Mini-Pareto traffic sample reproduced from video trace

The original bps sample and generated mini-Pareto video traffic bytes per second are shown in Fig.3.6; these kinds of large deviation from the video trace can never be reproduced by matching with the traditional Poisson process, neither Interrupted Poisson process.

4. Public safety simulation and overall performance evaluation

4.1 Simulation environment setting

As discussed earlier, OPNET can provide a platform to create and test an analytic and practical video model; it can also provide the ability to integrate the model into a VANET environment.

The common simulation parameters for each scenario are shown in Table 4.1 below, in places where parameters were changed for specific purposes, it will be indicated and discussed. Each simulation was simulated for a simulation time of 3600secs. The terrain dimensions vary slightly from scenario to scenario. They are an average of 1300 X 1250 m in area. The relative (x, y) position on the terrain is used to integrate the VANET mobility model trajectories and to obtain the initial positions of the vehicles. Vehicular environment for the path loss parameter is modeled according to the description in the "Radio Tx Technologies for IMT2000" white paper of the ITU. The shadow fading standard deviation was set to 10dB. The trajectories vary from scenario to scenario and will be discussed below.

4.2 Safety simulation scenarios

Two scenarios were chosen to simulate: school zone scenario, highway scenario. The goal was to study different geographic areas with varying traffic congestion, varying wireless interference and varying traffic speed limit.

We discuss below the specifications of model components in each scenario. In general, each scenario consists of N mobile nodes (Mobile Station on vehicle) and two BS to cover the geographical area represented. Performance measures such as end-to-end delay; usability (outage) will be evaluated and discussed for each scenario.

Parameter	*Value*
Physical layer	IEEE802.16e (WiMax)
Data rate	10Mbps
BS TX power	5 W
MS Tx power	1 W
Antenna type	Omni-directional
BS antenna gain	15dBi
MS antenna gain	9dBi
Link bandwidth	20MHz
Modulation scheme	16-QAM
Path loss parameter	Vehicular environment
Number of vehicles	10
Mobility model	VanetMobiSim
Number of RSU's	2
Simulated time	3600secs
Seeds	127
Terrain dimensions	1300x1250m

Table 4.1. OPNET simulation parameters

We study a network of 10 cars and 2 RSU's with each car has a maximum sustainable traffic rate of 384 Kbps except where otherwise stated. The link between the RSU and the backhaul network was a DS3 link with a capacity of 44.736 Mbps as shown in Fig.2.1. The buffer size at each SS was set to 256 KB except where otherwise stated. The simulation was run for 60 mins simulated time and the number of packets generated per node is about 10,000.

4.2.1 School safety scenario

This scenario was used to simulate a school zone with lots of stop signs and obstructions that can let children safely cross the road. The maximum speed in this scenario is 30 km/hr. The trajectory in this scenario was generated using specific formatting in VanetMobiSim. Fig. 4.1 show a screen shot of this scenario.

In this scenario, a mobility model with clusters was used to generate the trajectory for each node. The clusters are programmed to populate the scenario at random times during the simulation process to mimic the behaviour of a School zone environment. The path loss model to be applied to signals being received at the WiMAX MAC in this scenario was the "Vehicular Environment" model with shadow fading of 10 dB.

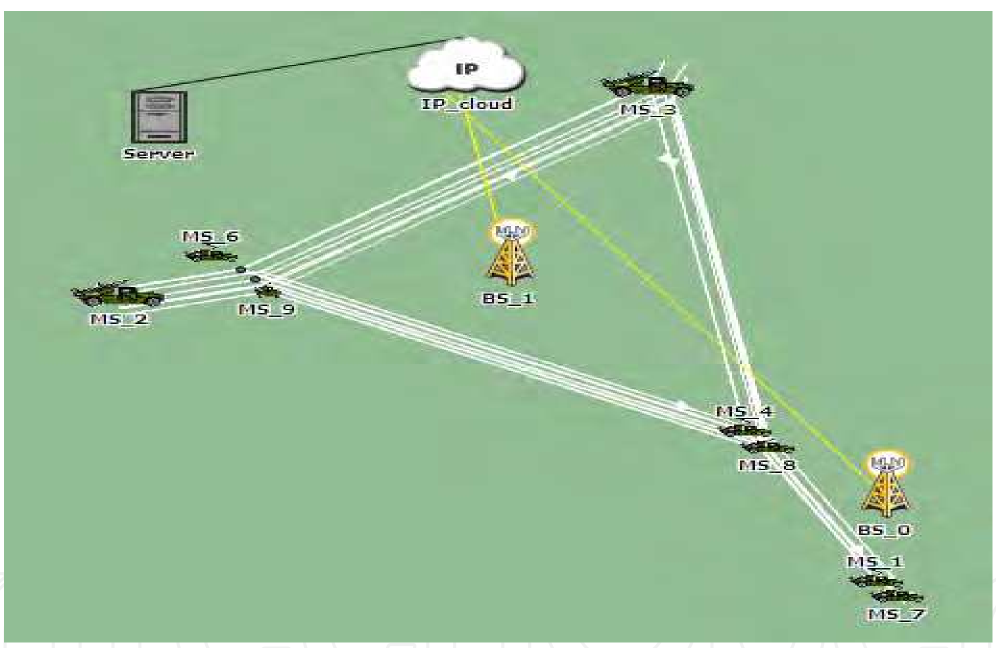


Fig. 4.1. School zone scenario with mobile trajectory

a. Mean end-to-end delay

Fig.4.2 shows the mean end-to-end delay performance as it varies with different buffer sizes and service rates. The mean end-to-end delay is seen to increase as the buffer size increases and decrease as the service rate increases. The curve is an increasing curve with a positive slope. This corresponds with the behaviour of a traffic that follows the Pareto distribution. The difference in the mean end-to-end delay for the service rates of 0.5 Mbps and 1 Mbps is not substantial. This is due to the fact that the school zone scenario has light traffic which implying that the delay is more and more dominated by other factors such as CPU speed different from the buffer capacity.

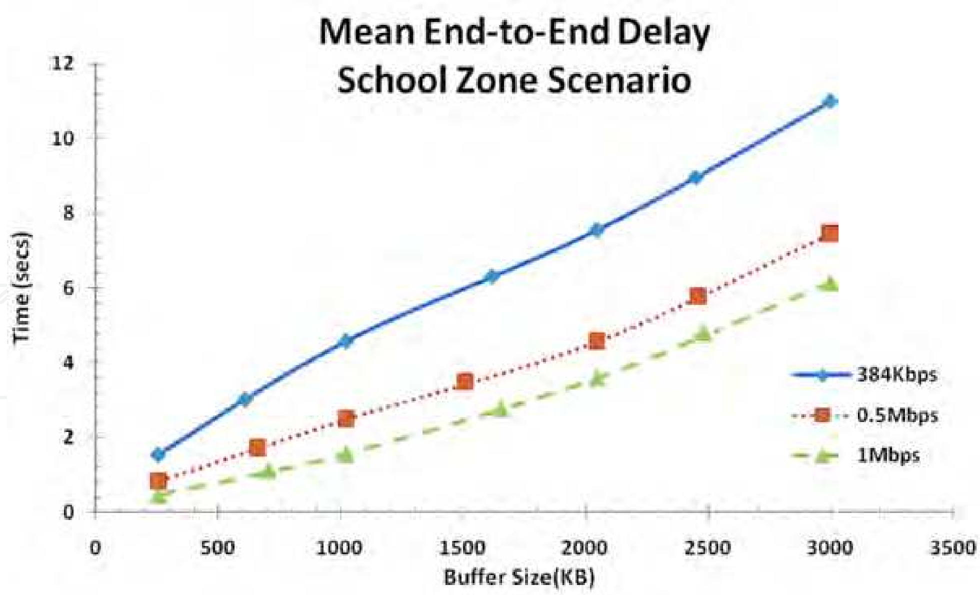


Fig. 4.2. Mean end-to-end delay performance for school zone scenario

b. Buffer overflow percentage

The percentage of buffer overflow is shown in Fig.4.3. When buffer overflow, packet is lost or delay is long and thus considered to be outage time. It is seen that at higher service rates the buffer does not saturate since the school zone scenario has lighter traffic as compared to the highway scenario.

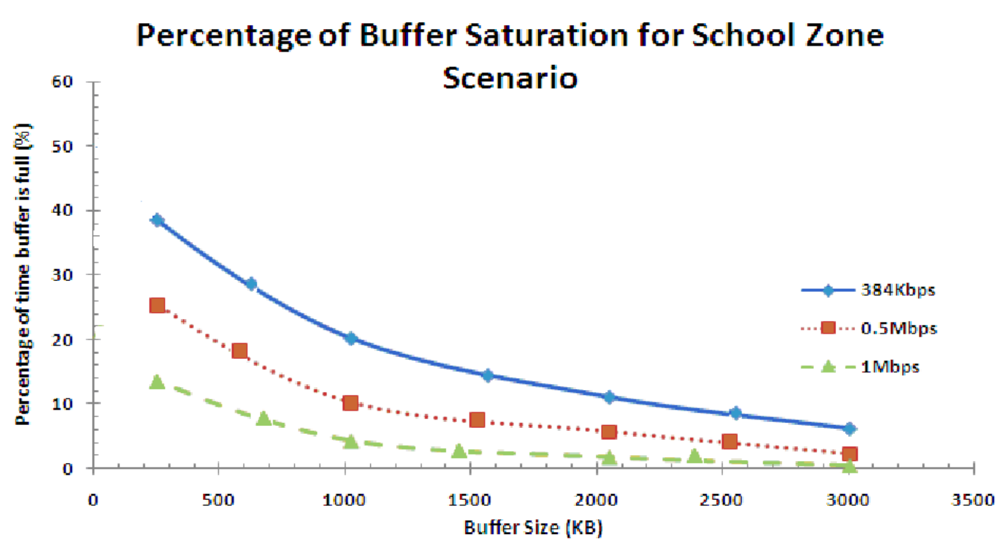


Fig. 4.3. Percentage of buffer saturation performance for school zone scenario

4.2.2 Highway safety scenario

This scenario was used to simulate the highway with a minimum speed of 60 km/hr and a maximum speed of 100 km/hr. In the trajectory of this scenario, the maximum number of traffic lights is one, just before the cars enter the highway. Fig.4.4 shows this scenario with the trajectory represented by the white lines shown.

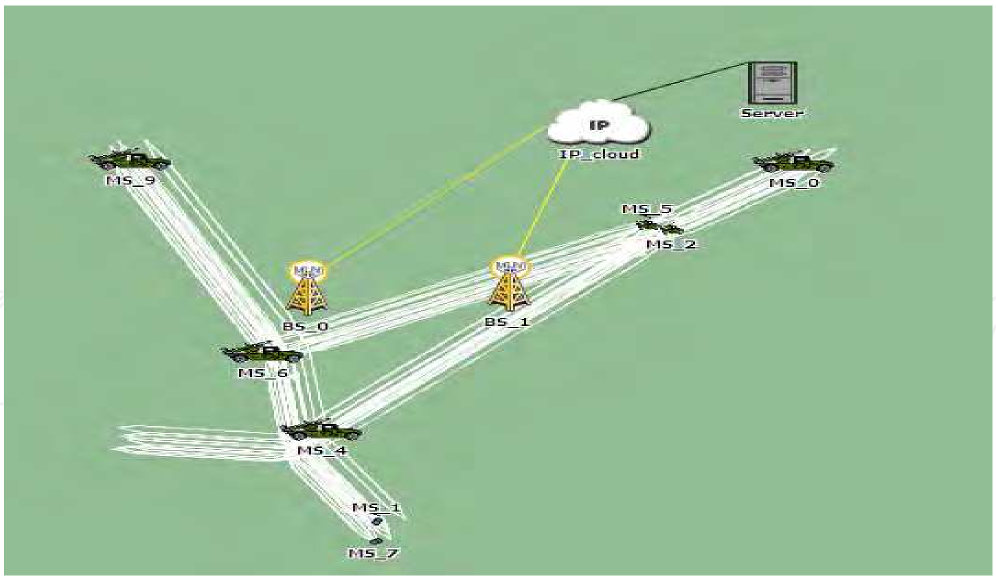


Fig. 4.4. Highway scenario with vehicle moving trajectory

The Highway scenario simulates an area where cars move at high speed of 100 km/hr.

a. Mean end-to-end delay

The mean end-to-end delay performance for the highway scenario is shown in Fig.4.5. As expected, as the service rate increases, the end-to-end delay reduces. However, one can see that the speed of the vehicles is a large factor here, compare with school zone, the situation is much worse for the same buffer size and the same service rate. Increasing the service rate reduces the end-to-end delay and increasing the buffer size increases the end-to-end delay.

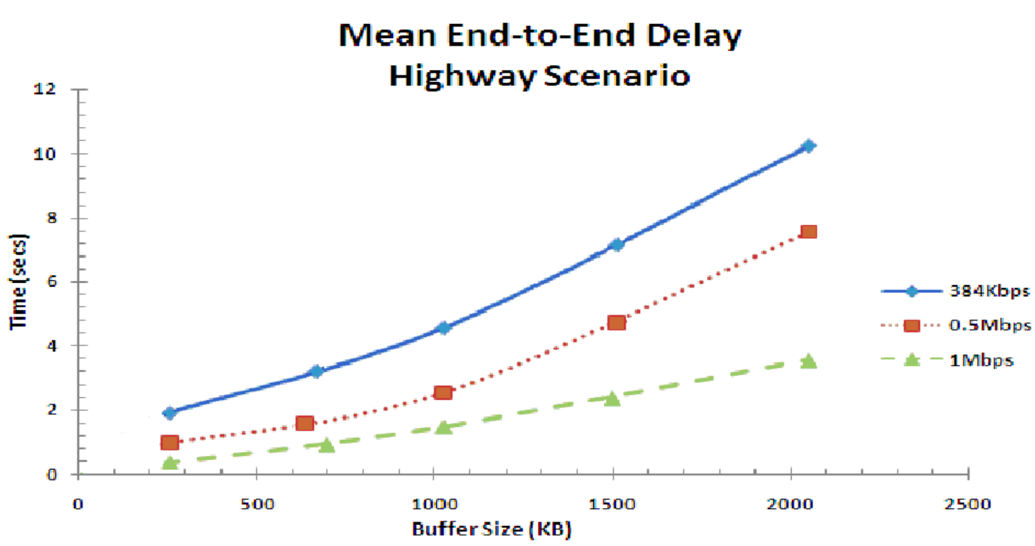


Fig. 4.5. Mean end-to-end delay performance for highway scenario

b. Buffer overflow (service outage) percentage

The percentage of buffer saturation of the Highway scenario is shown in Fig.4.6. The normal trend is followed in this case, i.e., as the buffer size increases, the percentage of time for which the buffer is full decreases. It is important to note that the reduction in percentage of buffer saturation as the service rate increases in this scenario might be caused by other factors such as, packet loss due to connection drops and reduced bandwidth. Again it is worse than School zone. By the way, the actual road tests we have conducted with police cars agree with this usability observation.

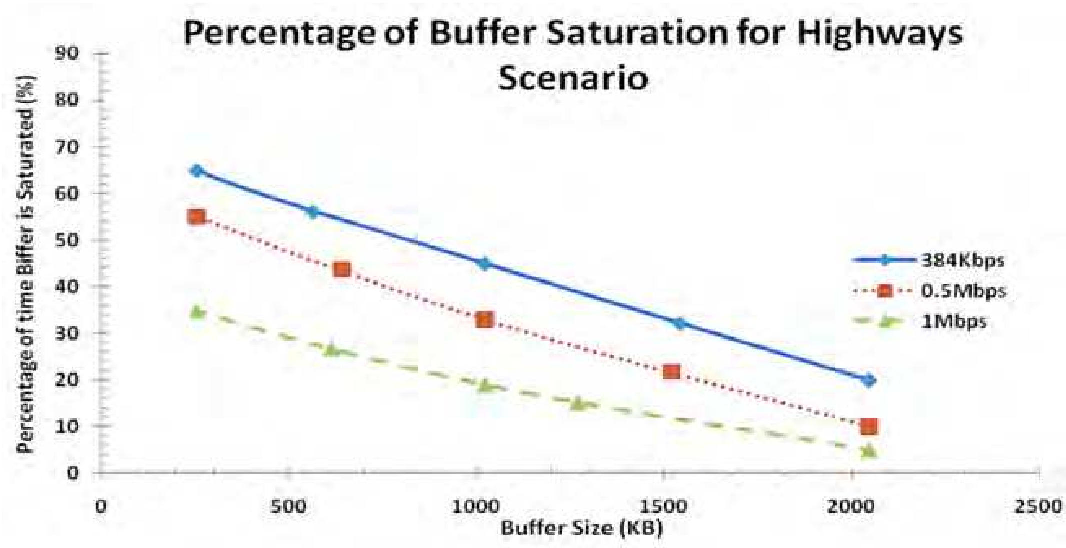


Fig. 4.6. Percentage of buffer saturation performance for highway scenario

5. Current implementation of the public safety wireless video system

With the past surge of the commercialization of the Internet, the continuing expansion of wireless services, and the increasing usage of multimedia applications, communication traffic demand has seen a steady increase. Researchers are diligently working towards disruptive technology that has not previously been given substantial attention narrowband wireless video applications to public safety.

Today's Internet does not provide the necessary QoS guarantees that are needed to support high-quality, real-time video transmission. Multimedia data transmitted over the Internet often suffers from delay, jitter, and data loss. Data loss, in particular, can be extremely damaging to compressed video since the intra-frame dependencies needed to achieve high-compression rates in video exacerbate the data loss when primary frames are lost. Unlike data applications, video applications can tolerate some short loss. A small gap in a video stream may not significantly impair media quality, and may not even be noticeable to users. However, long loss can result in unacceptable media quality, or service outage.

A number of techniques exist to repair packet loss in a media stream. These techniques have proven to be effective for audio stream data loss but may have yet to be applied to video, but in a significant different way. In particular, we propose a video interleaving approach to reduce the damage to a video stream from packet loss. Interleaving assumes that better perceptual quality can be achieved by spreading out bursty packet losses in a media flow. In other words, several unnoticeable short gaps degrade quality way less than a long gap in a multimedia flow. The basic idea of interleaving is to uniformly spread out long gaps in the video stream into several short gaps. In this way the effect of the loss of multiple consecutive frames is ameliorated, and the perceptual quality will be increased dramatically.

At the sender, frames in a video stream are first interleaved, with the original consecutive frames being separated by a specific distance that is given by the interleaving algorithm. After arriving at the receiver, frames are then reconstructed back to their original order. If consecutive loss occurs in the interleaved stream during transmission or as a result of single loss propagation, after reconstruction at the receiver, a long gap in the stream caused by the consecutive loss or propagated loss will be spread out into several unnoticeable short gaps.

This is different from audio interleaver in that no complicated Forward Error Correction is needed. Fig.5.1 shows the diagram of the wireless video streaming system. Video information is collected by the input video source, processed by the video encoder, interleaving system, channel encoder, modulator and transmitted through the transceiver to a destination. In the transmit chain explicitly shown in Fig.5.1, an interleaving system is used to interleave collected information. Video information received by the receiver is processed by the demodulator and the channel decoder. The de-interleaving system is employed to reverse the interleaving, which may be bit/byte/packet interleaving for example, applied to the received video information by an interleaving system at a transmitting device. De-interleaved video information is decoded by the video decoder, and output the video output device, which may be a display screen, for example. The particular structure and operation of the encoder may be different for different formats of video information, and the channel encoder, the modulator, and the transmitter will similarly be dependent upon communication protocols and media using which information is to be transmitted.

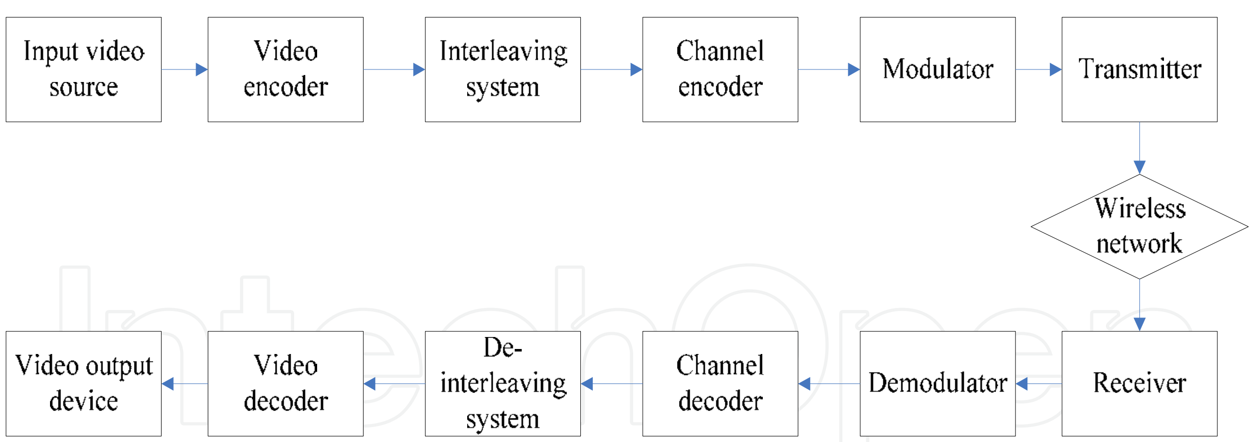


Fig. 5.1. System structure for breaking up long outage into short one

The interleaving system of Fig.5.2 implements an interleaving path which includes multiple interleavers, a packet interleaver, a frame interleaver, a byte interleaver, and a bit interleaver, each having a respective interleaving length. Also it includes a controller to control which interleavers are active in the interleaving path and thus the aggregate interleaving length at any time, a memory for storing information during interleaving and mappings between information types, operating conditions, and interleaving lengths.

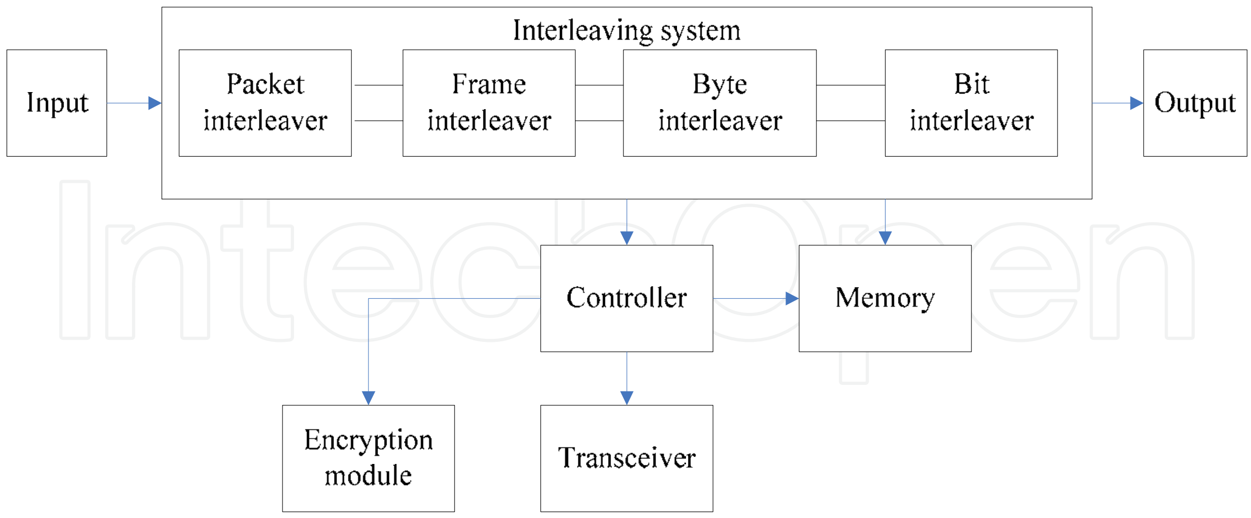


Fig. 5.2. Architecture of the degrading concealment interleaving system

Combining interleaving with encryption and watermark, instead of adding a stand-alone device, represents brand new thinking for lightweight all-in-one design philosophy. The hash key may be used to simply encrypt and mark the information itself, or to determine the position of original information after interleaving, rather than the complicated encrypting the actual information. Security information, a key for instance, can be combination of numerical number and alphabetical mark. We can pick a number from a password, if the password is “1326” and the frame interleaver is used for combined interleaving and encrypt marking, the first frame is swapped with the third frame in position, the second and the sixth frames are swapped, so on so forth, when the group of picture (frame) is set to 10. If the group of picture is set to 60, the key of “1646” will swap 16^{th} frame with 46^{th} frame. These rules could be exchanged using standard secured key exchange protocol as well.

Fig.5.3 shows a burst error reduction algorithm with adaptive control. It changes the interleaver size according to information provided by a run-time algorithm. Each sender and receiver receives video packets from each other, then analyzes the received video packet, and in particular video packet headers according to particular implementation, determines whether the sequence number of RTSP is damaged, and if the sequence number is changed, then the number of hops that the video packet passed is calculated. If the sequence number is not changed, then a current interleaving size is not changed, as indicated.

After calculating the number of hops, and also the number of errors reported on different layers at checkpoint for error, a determination is made, as to whether the overall error is above a threshold. If so, then interleaver size and thus interleaving length for an interleaving path is adjusted. If the number of hops for a packet is greater than 1, a runtime check for congestion on a communication link is performed. Illustrative examples of runtime checks are described in further detail below. If congestion is above a predetermined, selected, or remotely specified threshold, as determined, then interleaver dimension is changed, by enabling or disabling one or more additional interleavers.

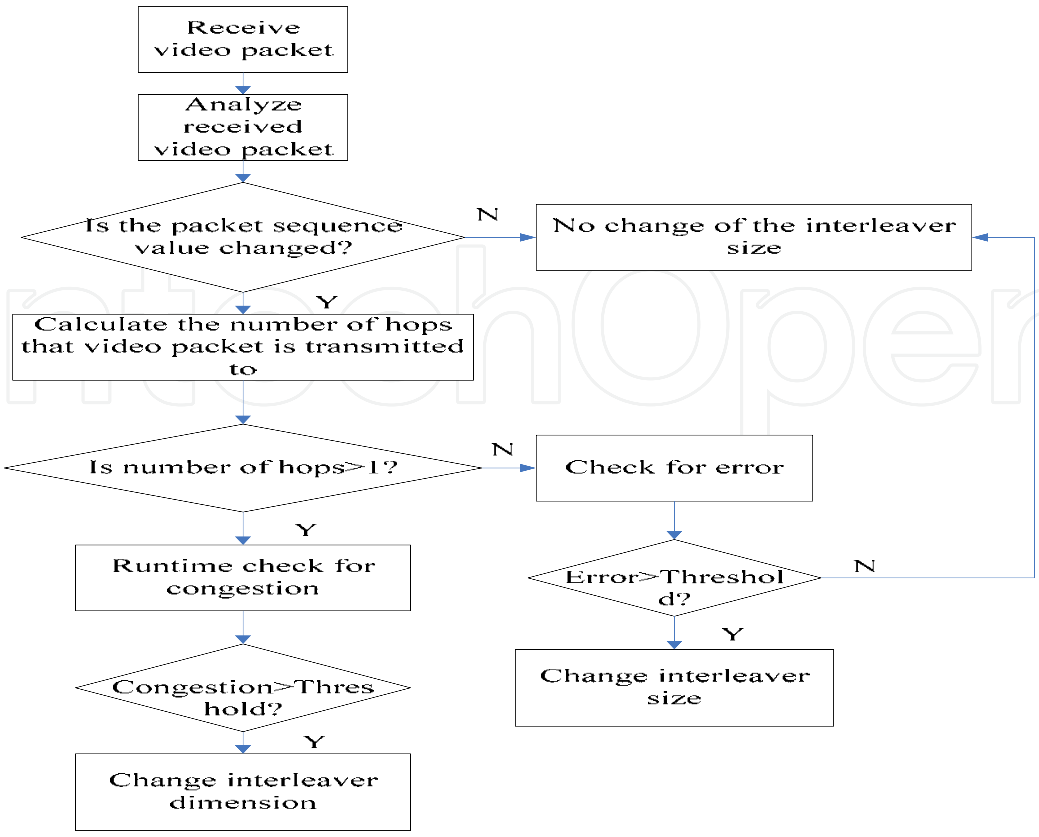


Fig. 5.3. Long burst impairment reduction algorithm

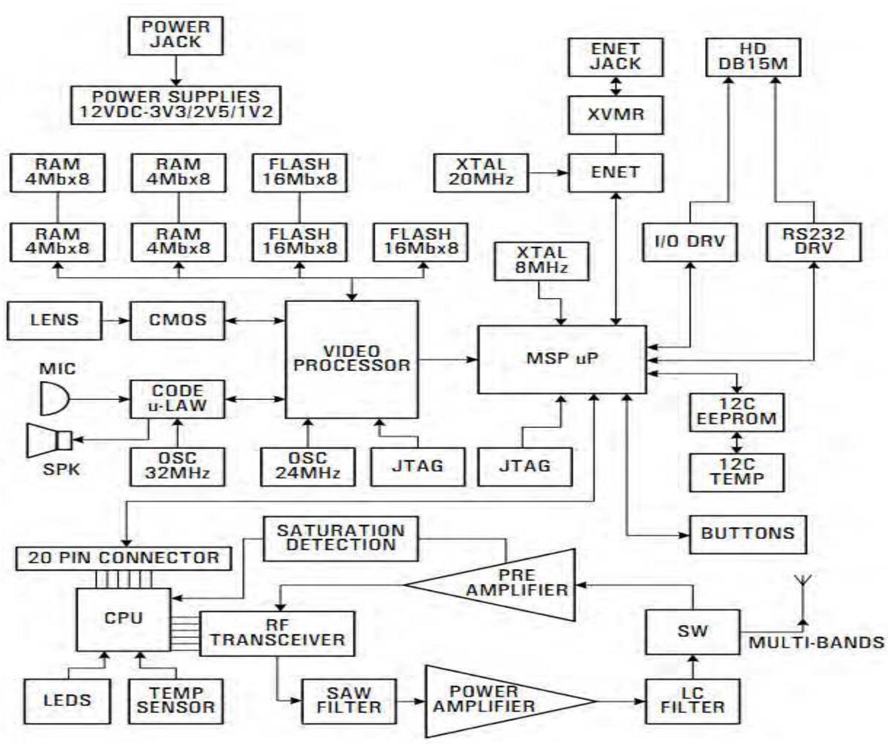


Fig. 5.4. Mobile terminal detail structure used in the experiment

Fig.5.4 is a block diagram of an example mobile terminal, including both wireless and video parts. Interleaving/integrity/and down sampling are mostly done in the Video processor, with some assistant from MSP Micro Processor for network layer related process, e.g. packet header filtering to distinguish other sensor signal from the video signal, and the third CPU for physical layer process, such as power amplifier saturation warning.

Deinterleaving/security and up sampling are done in Personal Computer for current product. And will be in the video processor or Field Programmable Gate Array (FPGA) chip in future product.

6. Conclusion

In this work, we were able to create an effective public safety WiMAX Ad-hoc video simulation platform with which other researchers can develop and test various public safety applications. This is done by designing our video model to work as individual sub-streams mini-Pareto model, matched with real trace from the actual car-to-car public safety camera. The platform was built using the OPNET simulation tool which allowed for the integration of all models – developed from statistically analysing a live video trace, real world map, trajectory simulations; and provided a complete tier of communication layers for proper performance analysis. This methodology does not limit itself to symmetrical wireless ad-hoc video traffic other situation applies as well.

Integrating a VANET mobility model into our platform created challenges for us. So far, due to the limitation of the OPNET library available, we have to run mobility model first before integrating the results into our communication model. It would have been best to run the simulation model and the mobility model concurrently to allow the wireless communication affect the mobility of vehicles so that more quick results can be obtained.

It is observed on the field that the scenario in which the application is deployed agrees with the performance obtained here in principal.

In summary, we were able to extend and implement a standard IEEE802.16 theoretical video model, integrate this new video model matched from WireShark real trace together with a VANET mobility model into the OPNET simulation tool, assisted by Matlab calculations.

7. Acknowledgement

The authors are grateful to Mr. Yanjun Chen and Prof. Yi Zhu of Jiangsu University, Prof. Oliver Yang of University of Ottawa, Prof. Lianfeng Shen of Southeast University, Prof. Zhiyong Zhang of Tamkang University, Prof. Tony Bailetti and Dr. Helen Tang of Carleton University, Prof. Zhen Liu of Jiangsu S&T University, Dr. Qiubo Ye and Hong Qian of CRC, Mike Zhou of RIM, Kathy Miao of IBM and Matt Woods of IP Unwired for their valuable contributions, comments, related discussions and constant encouragements during the research work lasted a decade long; also a number of public safety agencies in Canada and China for their diligent supporting of many unforgettable road tests!

8. References

Brit, E.(2010). WiMax. *Encyclopædia Britannica*. Accessed on 27 Jul. 2010. Available from http://www.britannica.com/EBchecked/ topic/1017801/WiMax

Chen, X. J., Chen, Z. J. & Xu, G. H. (2008). The research on routing protocol of sense wireless network in environmental monitoring. *Proceeding of the 4th International Conference on Wireless Communications, Networking and Mobile Computing*, pp.1-4, ISBN 978-1-4244-2107-7, Dalian, Oct 12-14, 2008

Duffy, K. R. & Sapozhnikov, A. (2007). The large deviation principle for the on/off weibull sojourn process. Journal of Applied Probability. Volume 45, pp.107-117

Fiore, M., Harri, J., Filali, F.& Bonnet, C.(2007). Vehicular Mobility Simulation for VANETs. *Simulation Symposium, 2007. ANSS '07. 40th Annual*, pp.301-309, ISSN 1080-241X Norfolk, vol., no., March 26-28, 2007

Feng, H. & Misra, V.(2003). Asymptotic bounds for $M^X/G/1$ processor sharing queues. *Technical report CUCS-006-04*, July 2003. http://www.cs.columbia.edu/~hanhua/

Ghosh, A. & Ghosh, M. (2007). *Fundamentals of WiMAX: Understanding Broadband Wireless Networking.* Prentice Hall, 2007

Gu, H. & Ji, Q. (2004). An automated face reader for fatigue detection. *Proceeding of Automatic Face and Gesture Recognition, Sixth IEEE International Conference,* pp. 111-116, ISBN 0-7695-2122-3, May 17-19, 2004

Huang, J. (2001). Presentation for Generalizing 4IPP Traffic Model for IEEE 802.16.3. *IEEE 802.16 Broadband Wireless Access Working Group,* Available from http://www.ieee802.org/16/tg3/contrib/802163p-00_58.pdf

Hong, S. H., Park, R. & Lee, C. B. (2001). Hurst parameter estimation of long-range dependent VBR MPEG Video traffic in ATM Networks. *Journal of Visual Communication and Image Representation,* Vol. 12, issue 1, March 2001, pp 44-65

Li, X., Huang, H. & Shu, W. (2009). VStore: Towards Cooperative Storage in Vehicular Sensor Networks for Mobile Surveillance. *Proceedings of IEEE Wireless Communication and Networking Conference,* pp.1-6, ISSN 0163-6804, Budapest, Hungary, April, 2009

Li, K.(2006). IEEE 802.16e- 2005 Air Interface Overview. *WiMAX Solutions Division Intel Mobility Group,* June 05, 2006

Morgan, Y.L. (2010). Managing DSRC & Wave Standards Suite Operations: In a V2V Scenario. *International Journal of Vehicular Technology*, Volume 2010, Available from http://www.hindawi.com/journals/ijvt/

Mehrvar, H., Le-Ngove, T. & Huang, J. (1996). Performance Evaluation of Bursty Traffic Using Neural Networks. *Proceeding of Canadian Conference Electrical and Computer Engineers,* pp.995-958, ISBN 0-7803-3143-5, Calgary, May 26-29, 1996

Song, G. & Oliver, Y. (2004). Minimum energy multicast routing for wireless Ad-hoc networks with adaptive antennas. *Proceeding of the 12th IEEE International Conference on Network Protocols.* ISSN 1092-1648, Oct 5-8, 2004

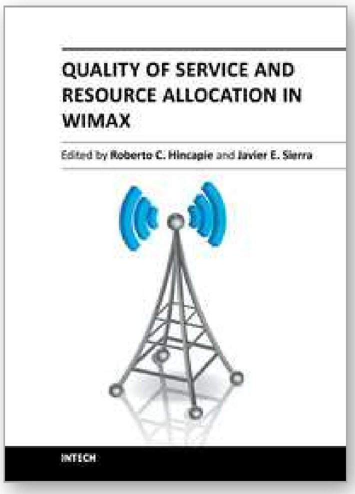
Sommer, C. & Dressler, F. (2008). Progressing toward Realistic Mobility Models in VANET Simulations, *IEEE Communication magazine*, vol. 46, no. 11, Nov. 2008, pp. 132-137, ISSN: 0163-6804

WiMa. (2009). IEEE WirelessMan 802.16. *The 802.16 WirelessMAN MAC: It's Done, but What Is It?* Available from
http:/ieee802.org/16/docs/01/80216-01_58rl/pdf, Accessed in 2009

Wegener, A., Hellbruck, H. & Wewetzer, C. (2008). VANET Simulation Environment with Feedback Loop and its Application to Traffic Light Assistance. *Proceedings of IEEE*

Globecom workshop, pp.1-7, *2008 IEEE,* ISBN 978-1-4244-3061-1, New Orleans,vol. 3, Nov. 30, Dec. 4, 2008

Zhou, L. Y. & Ji, W. W. (2010). A study on the application of WiMAX access technology in IPTV system Source. *Proceedings of the 2th International Conference on Networks Security, Wireless Communications and Trusted Computing,* pp.183-186, ISBN 978-0-7695-4011-5, April 2010



Quality of Service and Resource Allocation in WiMAX
Edited by Dr. Roberto Hincapie

ISBN 978-953-307-956-1
Hard cover, 376 pages
Publisher InTech
Published online 03, February, 2012
Published in print edition February, 2012

This book has been prepared to present state of the art on WiMAX Technology. It has been constructed with the support of many researchers around the world, working on resource allocation, quality of service and WiMAX applications. Such many different works on WiMAX, show the great worldwide importance of WiMAX as a wireless broadband access technology. This book is intended for readers interested in resource allocation and quality of service in wireless environments, which is known to be a complex problem. All chapters include both theoretical and technical information, which provides an in depth review of the most recent advances in the field for engineers and researchers, and other readers interested in WiMAX.

InTech Europe
University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

InTech China
Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821