A Complete Simulation Of Intra Vehicle Link Through Best PossibleWireless Network

Sourav Dhar, A.Ray, R.Bera, S.N.Sur and D.Ghosh

Abstract—**Vehicular safety is the prime objective of the Intelligent Transportation Systems. There is a need for "always connected" communication to ensure vehicular safety. This work presents a complete simulation of Intra Vehicle Link. Also the measured data, i,e, velocity of the vehicle, location and distance from other vehicles, from different sources, are fused using kalman filter and a vertical handover algorithm is developed using analytic hierarchy process for the choice of best possible wireless network from the available wireless networks. The fused data are communicated to target vehicle using the best possible wireless network among the available networks.**

Index Terms—**Analytic hierarchy process (AHP), Data fusion, Intelligent transportation systems (ITS), Intra vehicle link (IVL), Kalman filter, Collision avoidance and warning system (CAWAS)**

I. INTRODUCTION

INCREASING road accidents during early 90's forced most of the countries to pay more attention to reduce the casualties. The United States Department of Transportation has declared that the reduction of vehicular fatalities is its top priority.[1] This is true for all other countries as well. Also demand for voice, data and multimedia services, while moving in car increase the importance of Broadband wireless systems [2]. So, Intelligent Transportation Systems (ITS) are part of the national strategy for improving the security, safety, efficiency and comfort of every nation. ITS efforts to add remote sensing, information and communications technologies to transport infrastructure and vehicles to improve safety and reduce vehicle wear, transportation times, and fuel consumption etc. To be specific, remote sensing and vehicular communications are given highest priority for ITS.

Association for Intelligent Transport Systems INDIA (AITS) and **Intelligent Transport Systems Center of Excellence (India) are involved to promote the concept of road safety in India.** The Ministry of Science & Technology, INDIA; Ministry of Heavy Industries, INDIA; and Ministry of Urban Development, INDIA, all expressed their commitment towards SAVING LIVES, ENVIRONMENT, TIME & MONEY and keen interest to take up research, policy recommendations, programs and projects on ITS with AITS.   AITS India is an umbrella organization which represents a broad spectrum of members including industry, government, consumer organizations, and academia in fostering the development and deployment of Intelligent transport systems in India. Such systems often include components

used in electronic commerce, and related applications. AITS India also has strong links internationally with similar organizations including ITS America, ITS Australia and ITS Asia-Pacific [3].

The next-generation Mercedes-Benz S-Class has a revolutionary new safety system that can reduce rear collisions by 75 percent. The next evolution of Mercedes-Benz accident avoidance, PRE-SAFE uses two complementary radar frequencies (24GHz and 77 GHz) to detect vehicles up ahead, warn of a likely impact and prime the braking system for faster response when the driver brakes the car [4].

Application areas of ITS are highlighted in section II, Collision avoidance and warning system (CAWAS), which is a specific application area of ITS, is discussed in section III, the problem is defined in section IV, data fusion is discussed in section V, vertical handover is discussed in section VI, intra vehicle link (IVL) is discussed in section VII and conclusion in section VIII.

II. APPLICATION AREAS OF ITS

ITS applications can be broadly classified in two categories: safety applications and non safety application. Automatic cruise control (ACC), Driver assistance systems (DAS) and Collision avoidance and warning systems (CAWAS) are some examples of safety application. On the other hand, internet access from car, vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) communication, satellite television from car, radio taxi, and automatic toll collection are categorized as non-safety applications.

III. COLLISION AVOIDANCE AND WARNING SYSTEM

CAWAS is restricted for use in extra-urban roads (above 50Km/h), where the accidents are more dangerous. The possible scenarios are: roundabout, overtaking, roads intersection, roads junction, etc.

Fig.1: CAWAS scenario [5]
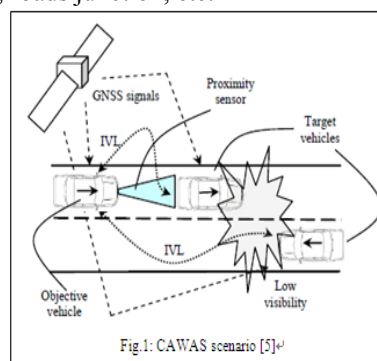
A typical CAWAS scenario is shown in Fig.1. The objective vehicle wants to overtake the obstacle (the 1st target

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vehicle), but second target vehicle is approaching in opposite direction and there are low visibility conditions. The three vehicles have GNSS receptors, local proximity and Intra Vehicle Link (IVL) communication systems. The objective vehicle calculates its current position, velocity and its situation in the road based on its own data (GNSS signals and GIS). Then, objective vehicle broadcast this information to the others vehicles and receive the corresponding information from the other vehicles trough IVL. The objective vehicle calculates its position and velocity relative to the others vehicles using the information received from the others vehicles. Additionally, objective vehicle has additional information about the car in front of it thanks to the proximity sensors. With this information, the CAWAS system in the vehicle is able to assess the collision risk with the others vehicles.

IV. PROBLEM DEFINITION

Objective of this work is to simulate an IVL between two vehicles through best possible wireless network. To achieve this objective, following steps are taken.

1) Position and velocity of the objective vehicle is arbitrarily taken. A set of values are considered as GNSS data and another set as proximity sensor's (Digital radar is considered here) measured data.

2) Kalman filter is used for data fusion and to estimate the actual position and velocity from two sets of data.

3) A vertical handover algorithm is developed and simulated. Result of the simulation decides the best possible wireless network among the available networks. Analytic hierarchy process (AHP) is used for the design of the vertical handover algorithm.

4) Finally the actual position of the objective vehicle and its velocity information is communicated to the target vehicle through IVL.

V. DATA FUSION

The rapidly evolving area of Information and Communication Technologies (ICTs) has clear implications for a range of travel demand management measures, spanning across the relevant user decision points, including the decisions to undertake activities, where to perform activities, and the transportation modes and routes to choose. Metropolitan areas today have quite literally become saturated with various types and sources of real-time data that can, in theory, be utilized to improve mobility services by influencing demand, allowing users to make better-informed decisions about their mobility via seamless integration and delivery of the necessary information (including prices and externalities), when and where it is needed. These data sources include "traditional" transportation sources, often associated with Intelligent Transportation Systems (ITS), such as toll road operators, public transportation services, road sensors, image capturing and commercial fleet tracking.

At the same time, the increasing ubiquity of a range of different mobile devices and other ICT-related technologies introduces new information sources, including distributed mobile sensor networks, mobile devices, direct citizen engagement, and web-based platforms which provide close-to-real-time information (e.g. on city events).

Data fusion (DF) [6] involves the seamless detection and combination of data, from multiple sources, with the goal of extracting new knowledge from the data and generating improved information (including estimations, predictions) that can be transmitted to relevant users for better decision making. More specifically, we consider that a system uses *data fusion* whenever:

- More than one source of data is being fed simultaneously;
- Each data source has distinct inherent properties (i.e. specific technology, type of data, etc.); and,
- Data sources are integrated to create at least one sort of unified information.

A. Kalman Filter [6,7]

We need an accurate estimate of the process variables in order to control a process using embedded control systems. *Theoretically* the Kalman Filter is an estimator for what is called the *linear-quadratic problem,* which is the problem of estimating the instantaneous "state" (a concept that will be made more precise in the next chapter) of a linear dynamic system perturbed by white noise—by using measurements linearly related to the state but corrupted by white noise. The resulting estimator is statistically optimal with respect to any quadratic function of estimation error. Practically, it is certainly one of the greater discoveries in the history of statistical estimation theory and possibly the greatest discovery in the twentieth century. It has enabled humankind to do many things that could not have been done without it, and it has become as indispensable as silicon in the makeup of many electronic systems. it is not always possible or desirable to measure every variable that you want to control, and the Kalman filter provides a means for inferring the missing information from indirect (and noisy) measurements.

B. Kalman Filter in Data Fusion

The Kalman filter can be summed up as an optimal recursive computation of the least-squares algorithm. It is a subset of a Bayes Filter where the assumptions of a Gaussian distribution and that the current state is linearly dependant on the previous state are imposed. In other words, the Kalman filter is essentially a set of mathematical equations that implement a predictor-corrector type estimator that is optimal in the sense that it minimizes the estimated error covariance when the condition of a linear- Gaussian system is met. If the Gaussian assumption is relaxed, the Kalman filter is still the best (minimum error variance) filter out of the class of linear unbiased filters. From the time it was developed, the Kalman has been the subject of extensive research and application, especially in the field of navigation. The simple and robust nature of this recursive algorithm has made it particularly appealing. Also, even though it is rare that the optimal conditions exist in real-life applications, the filter often works quite well in spite of this and thus contributes to its appeal.

C. Discrete Kalman Filter Algorithm

This section describes the filter in its original formulation (Kalman 1960) where the measurements are measured and

state estimated at discrete points in time. Dynamic systems (this is, systems which vary with time) are often represented in a state-space model. State-space is a mathematical representation of a physical system as a set of inputs, outputs and state variables related linearly. The Kalman filter addresses the general problem of trying to estimate the state of a discrete-time controlled process that is governed by the models shown in fig. 2.
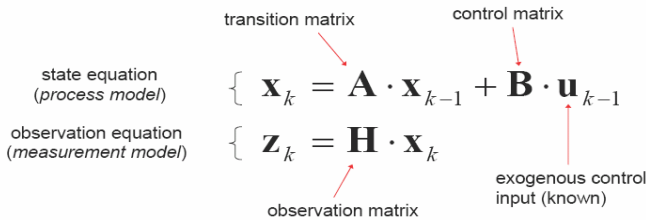

Fig.2: Model of a discrete-time controlled process

In addition to this, a random, Gaussian, white noise source $\mathbf{w_k}$ and $\mathbf{v_k}$ are added to the state and observation equations respectively. The process noise $\mathbf{w}$ has a covariance matrix Q and the measurement noise $\mathbf{v}$ has a covariance matrix R, which characterizes the uncertainties in the states and correlations within it.

At each time step, the algorithm propagates both a state estimate $\mathbf{x_k}$ and an estimate for the error covariance P_k, also known as a priori estimates. The latter provides an indication of the uncertainty associated with the current state estimate. These are the predictor equations. The measurement update equations (corrector equations) provide a feedback by incorporating a new measurement value into the a priori estimate to get an improved a posteriori estimate. The equations for this recursive algorithm are shown in fig. 3.:
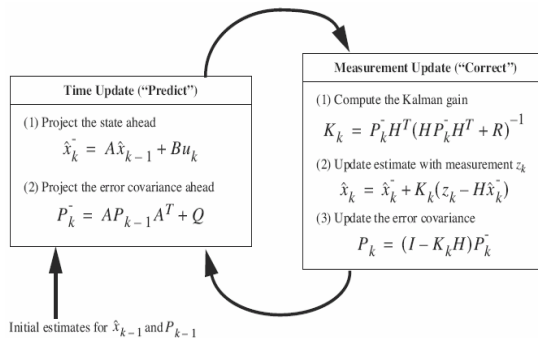

Fig.3: The equations for the recursive algorithm used for Kalman filter

The Kalman Gain (K in measurement update equation 1) is derived from minimizing the a posterior error covariance . What the Kalman Gain tells us is that as the measurement error covariance R approaches zero, the actual measurement $\mathbf{z}$ is "trusted" more and more, while the predicted measurement $H\hat{x}$ is trusted less and less. On the other hand, as the a priori estimate error covariance $\mathbf{P}$ approaches zero the actual measurement is trusted less and less, while the predicted measurement is trusted more and more.

D. Kalman Filter algorithm

Suppose we have a linear system model as described previously. We want to use the available measurements y to estimate the state of the system x. We know how the system

behaves according to the state equation, and we have measurements of the position, so how can we determine the best estimate of the state x? We want an estimator that gives an accurate estimate of the true state even though we can't directly measure it. What criteria should our estimator satisfy? Two obvious requirements come to mind. First, we want the average value of our state estimate to be equal to the average value of the true state. That is, we don't want our estimate to be biased one way or another. Mathematically, we would say that the expected value of the estimate should be equal to the expected value of the state.

Second, we want a state estimate that varies from the true state as little as possible. That is, not only do we want the average of the state estimate to be equal to the average of the true state, but we also want an estimator that results in the smallest possible variation of the state estimate. Mathematically, we would say that we want to find the estimator with the smallest possible error variance. It so happens that the Kalman filter is the estimator that satisfies these two criteria. But the Kalman filter solution does not apply unless we can satisfy certain assumptions about the noise that affects our system. Remember from our system model that w is the process noise and z is the measurement noise. We have to assume that the average value of w is zero and the average value of z is zero. We have to further assume that no correlation exists between w and z. That is, at any time k, w_k, and z_k are independent random variables. Then the noise covariance matrices S_w and S_z are defined as:

Process noise covariance

$$S_w = E(w_k w_k^T)$$

Measurement noise covariance

$$\mathbf{S}_z = E(z_k z_k^T)$$

where w^T and z^T indicate the transpose of the w and z random noise vectors, and E(·) means the expected value.

Now we are finally in a position to look at the Kalman filter equations. There are many alternative but equivalent ways to express the equations. One of the formulations is given as follows:

$$K_k = AP_k C^T \left(CP_k C^T + S_z\right)^{-1}$$

$$\hat{x}_{k+1} = \left(A\hat{x}_k + Bu_k\right) + K_k\left(y_{k+1} - C\hat{x}_k\right)$$

$$P_{k+1} = AP_k A^T + S_w - AP_k C^T S_z^{-1} CP_k A^T$$

That's the Kalman filter. It consists of three equations, each involving matrix manipulation. In the above equations, a -1 superscript indicates matrix inversion and a T superscript indicates matrix transposition. The K matrix is called the Kalman gain, and the P matrix is called the estimation error covariance. The state estimate ( ) equation is fairly intuitive. The first term used to derive the state estimate at time $k + 1$ is just A times the state estimate at time k, plus B times the known input at time k. This would be the state estimate if we didn't have a measurement. In other words, the

state estimate would propagate in time just like the state vector in the system model.

The second term in the $\hat{X}$ equation is called the *correction term* and it represents the amount by which to correct the propagated state estimate due to our measurement.

Inspection of the K equation shows that if the measurement noise is large, S_z will be large, so K will be small and we won't give much credibility to the measurement y when computing the next. On the other hand, if the measurement noise is small, S_z will be small, so K will be large and we will give a lot of credibility to the measurement when computing the next $\hat{X}$.

E. Data Fusion In ITS

Data fusion in Intelligent Transport System is the combination of data obtained from GPS/AGPS and local RADAR to get a better result.

In ITS, we look to avoid accidents. Hence we use GPS receivers to know others location, distance from us, and there velocity. As we know that GPS doesn't give an accurate result, there are some errors. To avoid these errors we use local radar so that we can get a better estimate of the distance and velocity of the things which are closer to us.

Now for collision avoidance, the distance which is to be displayed in the LCD screen in front of the driver should be the least between the vehicles and the velocity should be the maximum. The main reason behind this assumption is that if the distance displayed is more than the actual one then there is a chance of collision as the driver will not get the right information regarding the distance. Also if the distance shown is minimum then also the driver will not get the right information regarding the distance but he can stop the vehicle before any collision, as there is a famous saying that "better be Mr. late than late Mr." . Again velocity shown should be maximum so that the driver will stop the vehicle as early as possible.

F. Data Fusion Model

A data fusion model is developed using Matlab Simulink as shown in fig. 6. We have used a random source to test our model. The random source is then passed through a channel (as shown in fig. 4) to make some distortion in it. To recover the data from noisy environment we have used kalman filter (shown in fig. 4). The data which is recovered is very much closed to the original one (shown in fig. 5). This process is followed to just check the efficiency of kalman filter. Now the fusion block compares the data i.e the distance given by GPS and that by RADAR. The least distance is then forwarded to the IVL model. Again the velocity given by the GPS as well as by that of RADAR is compared and then the maximum velocity is forwarded. The reason for the minimum distance and maximum velocity is- Suppose the distance between two vehicles is 10m and the distance shown is 12m, then there is a chance that the driver may stop around 10-11m,but the actual distance is near to 10m, so there is a chance of collision between the vehicles, but what if the distance shown is 10m, the driver will definitely stop the vehicle at a distance less than 10m. Though it may be less

than the actual distance but the goal of saving life is achieved as collision is avoided. The result of data fusion is shown in fig. 7. It is clear from this result that the local radar measurement is more accurate than the GPS measurement.
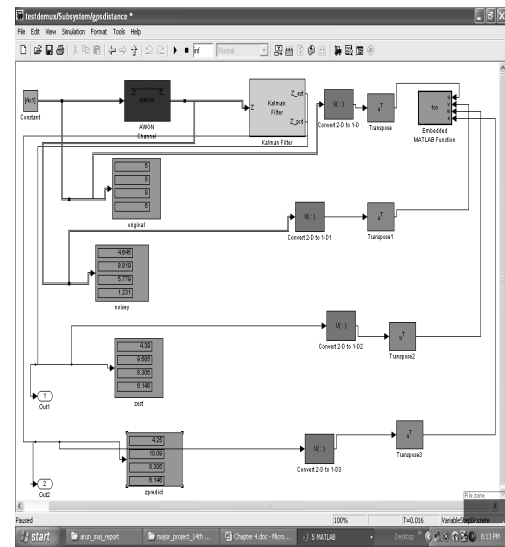

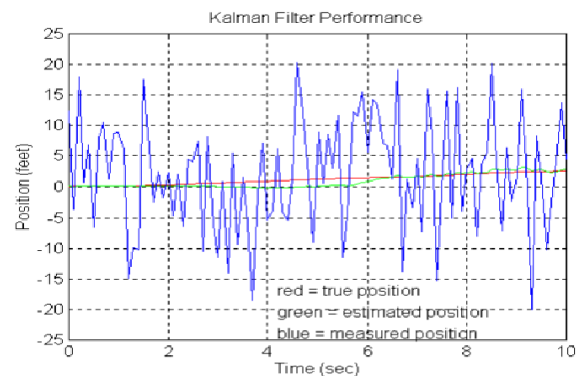Fig.4. Recovery of data from noisy environment
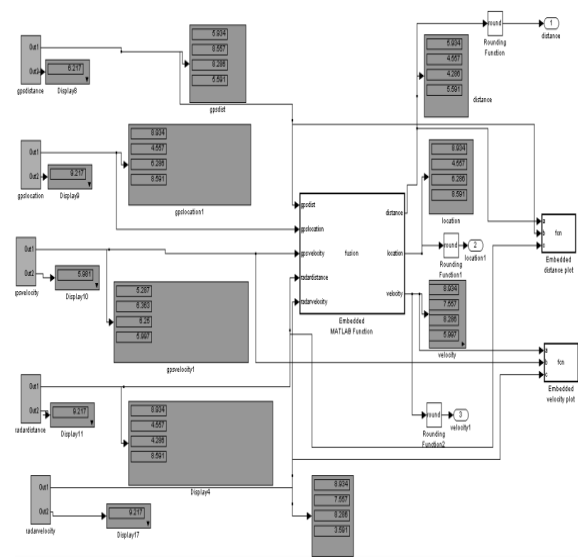

Fig. 5. Performance of Kalman filter

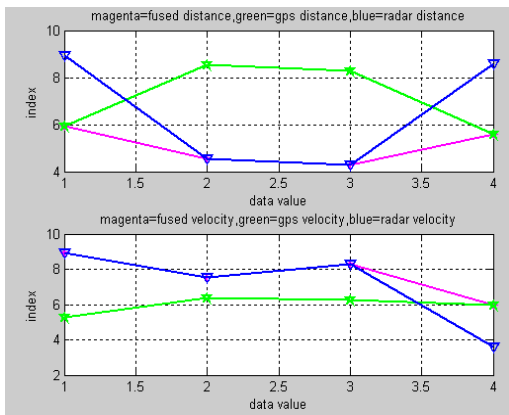Fig. 6. Data Fusion Block using Matlab Simulink.

Fig. 7: Fused data

VI. VERTICAL HANDOVER ALGORITHM

In a transportation system, vehicles are on the move and covering a large distance. In its way it will be in and out of many wireless cells. At a particular position, there may be more than one network (WLAM, WCDMA, WiMAX) available. On the other hand it may happen that the desired network, through which the vehicle is communicating currently, is not available at a particular area. Thus it is required to change the network immediately to ensure QoS. *Vertical handoff* enables seamless terminal, personal and network mobility. It provides for continuity and transfer of existing sessions. Vertical handoff can be separated into three phases: network discovery, handoff decision, and handoff execution [8]. Traditional handoff decision metrics based on the received signal strength indication (RSSI) and other physical layer parameters used for horizontal handoff in cellular systems are insufficient for the challenges of a heterogeneous wireless system. In order to take an intelligent and better decision as to which wireless network should be chosen and make it possible to deliver each service via the network that is the most suitable for it, the analytic hierarchy process based vertical handoff algorithm is simulated here. Along with received signal strength, the data rate, cost of the service and most importantly the effect of the vehicle speed are considered.

A. Analytic hierarchy process

Analytic hierarchy process [9]–[18] is a decision support tool developed by Saaty in which ideas, feelings, and emotions are qualified based on subjective criteria to provide a numeric scale for prioritizing decision alternatives. It deals with complex, unstructured, and multiple criteria decisions. Patrovi [19] explains the process in three broad steps: the description of a complex decision problem as a hierarchy, the prioritization procedure, and the calculation of results. In this method, a problem is put into a hierarchical structure as follows:
1) The overall objective of the decision.
2) Factors or criteria for the decision
3) Sub-factors under those factors
4) The decision options.

The steps involved for an AHP model are as follows:
Step-1: Construct a decision matrix. Each element of the matrix is based on Saaty's nine-point scale (Table I). The comparison matrix reflects the decision maker's judgment of the relative importance of the different criteria. The pair-wise comparison is made such that the criterion in row i ($i = 1, 2, 3 \ldots n$) is ranked relative to each of the criteria represented by the n columns.

Step-2: Develop a normalized matrix by dividing each number in a column of the pair-wise comparison matrix by its column sum.

Step-3: Average each row of the normalized matrix. These row averages form the priority vector of alternative preferences with respect to the particular criteria.

Step-4: To determine whether or not a level of consistency is reasonable, we need to develop a quantifiable for the comparison matrix. If w is the column vector of the relative weight w_i ($i = 1, 2, 3 \ldots n$), comparison matrix A is consistent if $Aw = nw$.

Step-5: Using AHP, compute the consistency ratio as $CR = CI/RI$

Where CI = consistency index of comparison matrix = $(n\max - n)/(n - 1)$
and
RI = Random inconsistency = $[1.987(n - 2)]/n$

Step-6: If the consistency ratio is <10%, then the level of inconsistency is acceptable. Otherwise, the inconsistency A is high, and the elements of the decision matrix must be revised.

TABLE I. THE NINE-POINT SCALE OF PAIR-WISE COMPARISON

Intensity of relative importance	Definition
1	Equally important
3	Moderately preferred
5	Equally preferred
7	Very strongly preferred
9	Extremely preferred
2,4,6,8	Intermediate judgment between two adjacent judgments

B. Design and simulation of VH algorithm

AHP matrix For deciding priority among the following criteria for choosing one network: Cost of service, SNR, Vehicle Speed, Data Rate.

AHP matrix:

	COST	SNR	SPEED	DATA RATE
COST	1	1/9	1/9	1/5
SNR	9	1	1	9/5
SPEED	9	1	1	9/5
DATA RATE	5	5/9	5/9	1
SUM	24	2.67	2.67	4.8

Normalized Matrix:

	COST	SNR	SPEED	DATA RATE
COST	0.042	0.042	0.042	0.042
SNR	0.375	0.375	0.375	0.375
SPEED	0.375	0.375	0.375	0.375
DATA RATE	0.208	0.208	0.208	0.208
SUM	1	1	1	1

Priority Vector:

W=

0.042
0.375
0.375
0.208

Result:

SNR = Speed > Data Rate > Cost

To check consistency:

Principle Eigen Value (λ_{max}) = 0.042×24 + 0.375×2.67 + 0.375×2.67 + 0.208×4.8   = 4.0089

CI(Consistency Index) = $\dfrac{\lambda_{max} - n}{n - 1}$ 0.002966

where n → size of matrix (In this case = 4)

CR (Consistency Ratio) =

$$\dfrac{CI}{RI} = \dfrac{0.002966}{0.9} = 0.3296\% \ < 10\%$$

Hence the decision matrix and the decisions are consistent in nature. And for ITS availability of the network and speed of the vehicle are assigned highest priority and then application (data rate) followed by cost of the service.

AHP matrix for deciding priority of each network based on Data Rate alone:

Data Rate	WiMAX	WLAN	WCDMA
WiMAX	1	5	9
WLAN	1/5	1	3
WCDMA	1/9	1/3	1
SUM	1.31	6.33	13

Normalised Matrix:

Data Rate	WiMAX	WLAN	WCDMA
WiMAX	0.76	0.789	0.692
WLAN	0.153	0.158	0.023
WCDMA	0.085	0.0526	0.0769

Priority Vector:

W = 0.747
     0.18
     0.0715

Result:

WiMAX > WLAN > WCDMA

To check consistency:

Principle Eigen Value (λ_{max})
=1.311×0.746 + 6.3333×0.179 + 13×0.0713   = 3.038

CI(Consistency Index) = $\dfrac{\lambda_{max} - n}{n - 1}$ 0.019

where n → size of matrix (In this case = 3)

CR(Consistency Ratio) = $\dfrac{CI}{RI} = \dfrac{0.019}{0.58} = 3.27\% < 10\%$

Hence the decision matrix and the decisions are consistent in nature.

For deciding priority of each network based on Mobility alone:

Mobility	WiMAX	WLAN	WCDMA
WiMAX	1	9	3
WLAN	1/9	1	1/7
WCDMA	1/3	7	1
SUM	1.44	17	4.14

Normalised Matrix:

Mobility	WiMAX	WLAN	WCDMA
WiMAX	0.69	0.53	0.725
WLAN	0.077	0.058	0.0345
WCDMA	0.231	0.412	0.2415

Priority Vector:

W = 0.648
     0.0565
     0.295

Result:

WiMAX > WCDMA > WLAN

To check consistency:

Principle Eigen Value (λ_{max}) =1.44×0.648 + 17×0.0565 + 0.295×4.14 =3.08

CI(Consistency Index) = $\dfrac{\lambda_{max} - n}{n - 1}$ 0.04

where n → size of matrix (In this case = 3)

CR(Consistency Ratio) = $\dfrac{CI}{RI} = \dfrac{0.04}{0.58} = 6.8\% < 10\%$

Hence the decision matrix and the decisions are consistent in nature.

For deciding priority of each network based on cost alone:

Cost	WiMAX	WLAN	WCDMA
WiMAX	1	1/7	1/5
WLAN	7	1	3
WCDMA	5	1/3	1
SUM	13	1.476	4.2

Normalised Matrix:

Cost	WiMAX	WLAN	WCDMA
WiMAX	0.0769	0.0967	0.0476
WLAN	0.538	0.677	0.714
WCDMA	0.385	0.226	0.23

Priority Vector:

W = 0.0737
     0.643
     0.28

Result:

WLAN > WCDMA > WiMAX

To check consistency:

Principle Eigen Value (λ_{max}) =13×0.0737 + 0.643×1.476 + 0.28×4.2   =3.08

CI(Consistency Index) = $\dfrac{\lambda_{max} - n}{n - 1}$ 0.04

where n → size of matrix (In this case = 3)

CR(Consistency Ratio) = $\dfrac{CI}{RI} = \dfrac{0.04}{0.58} = 6.8\% \ < 10\%$

Hence the decision matrix and the decisions are consistent in nature.

VII. SIMULATION

Fig. 8 shows the SIMULINK model developed for network selection for ITS. A display shows the final priority vector value. Network with highest value is the selected network. Fig. 9 elaborates the decision box of Fig. 8. Here AHP for individual criteria are calculated and given as input

to the final AHP calculation block.

It is assumed for simulation that the cost of the service is least for WLAN followed by WCDMA and WiMAX. It is further assumed that all the networks are available all the time but their signal strength can vary depending on situation. Two situations are considered here. First, it is assumed that the vehicle is near to a toll plaza, where WLAN signal strength is more than others. DSRC (Dedicated short range communication) based WLAN is operational for automatic toll collection in USA, Japan and Europe [20]. Thus this situation is simulated. Second one is a highway situation where WCDMA signal strength is more compared to WLAN and WiMax. This situation is considered as WCDMA covers a huge area whereas WLAN covers only up to 200meters and WiMAX is basically available within a city.

Received signal strength (received SNR) for different networks considered for simulation are specified in Table II.
Simulation Parameters

Table II

Received signal strength for different networks considered for simulation

	WLAN SNR	WCDMA SNR	WiMAX SNR
Near Toll Plaza	25db	15db	12db
Highway situation	12db	20db	12db

VIII. RESULTS

From the Fig. 10 it is evident that at lower vehicle speed (up to 22Kmph) WLAN is the selected network for conversational traffic and up to 25kmph for streaming traffic. For higher vehicular speed (more than 26 Kmph for streaming and more than 57 Kmph for conversational traffic) WiMAX is the preferred technology. For moderate speed (from 23Kmph to 57 Kmph) WCDMA is preferred technology for conversational application. Interestingly, for streaming application WCDMA is not preferred at all if either of WLAN or WiMAX are available. This due to the fact that WLAN and WiMAX support much higher data rate compared to WCDMA.

Fig. 11 explains a highway situation when vehicle is bit far from WLAN and WiMAX base stations and WCDMA signal strength is comparably higher. Under this situation WCDMA is the preferred network up to 64Kmph for conversational traffic and above this speed WiMAX is preferred. For streaming application WiMAX is always favored even if the received signal strength is less compared to WCDMA.
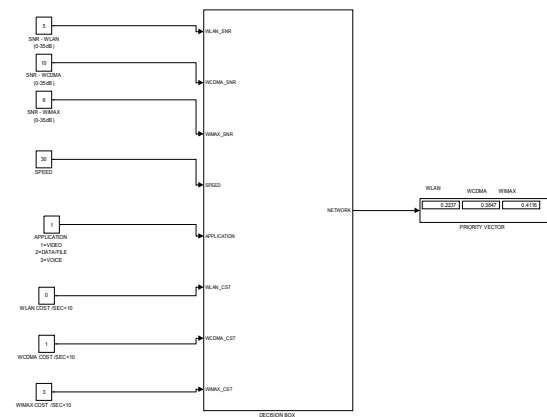

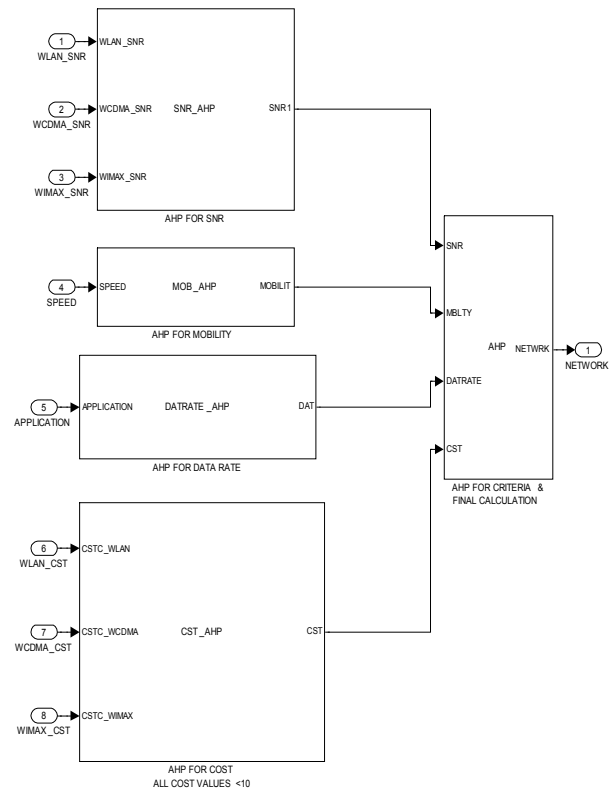Fig 8: Snapshot of Simulink model for program using AHP

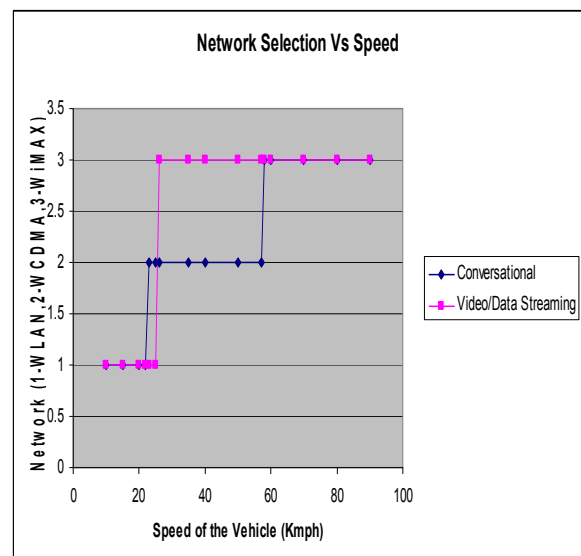Fig.9 : Sub-system for calculating individual priorities

Fig. 10: Variation in network selection with vehicle speed (near Toll plaza)

IX. EXPLANATION OF SIMULATION MODEL OF IVL

Data communication is the principal requirement for CAWAS. Results of section VI has shown that WiMAX is the selected network for data communication. Further it is shown that WiMAX serves better at higher vehicular speed compared to the other technologies. Thus we have developed an IVL model using WiMAX technology (fig. 12). Using this model the fused relative distance, velocity of the objective vehicle and their location are communicated between objective vehicle and the target vehicle.
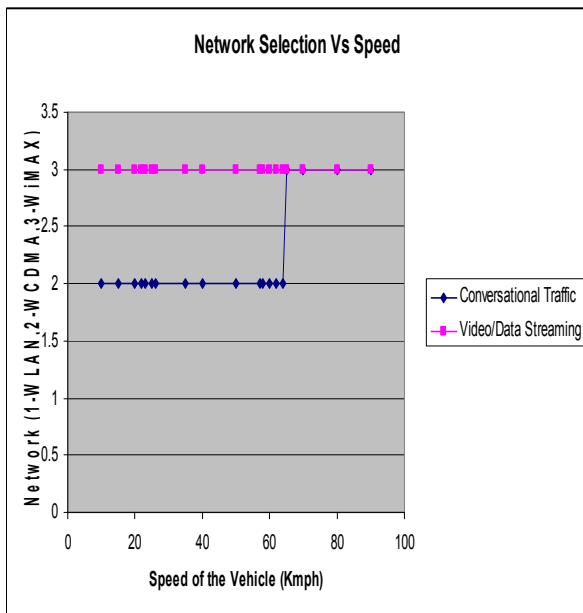

Fig. 11: Variation in network selection with vehicle speed (Highway Situation)

X. DISCUSSION AND CONCLUSION

Simulation of a CAWAS was the principal objective of this work. In this process a novel method for network selection is developed and successfully simulated. As CAWAS works in extra-urban roads (above 50Km/h), where the accidents are more dangerous, a seamless communication is required to avoid collisions.

Our literature survey reveals that this is the first time when a complete simulation of intra vehicle link (IVL) is presented where the best possible technology is chosen according to an adaptive algorithm.

All the requirements are designed and simulated and satisfactory results are presented here. This choice of wireless technology is valid for data communication at a high speed (above 50kmph). We have considered four significant criteria. There is scope for further research in the areas where vehicle speed is less.

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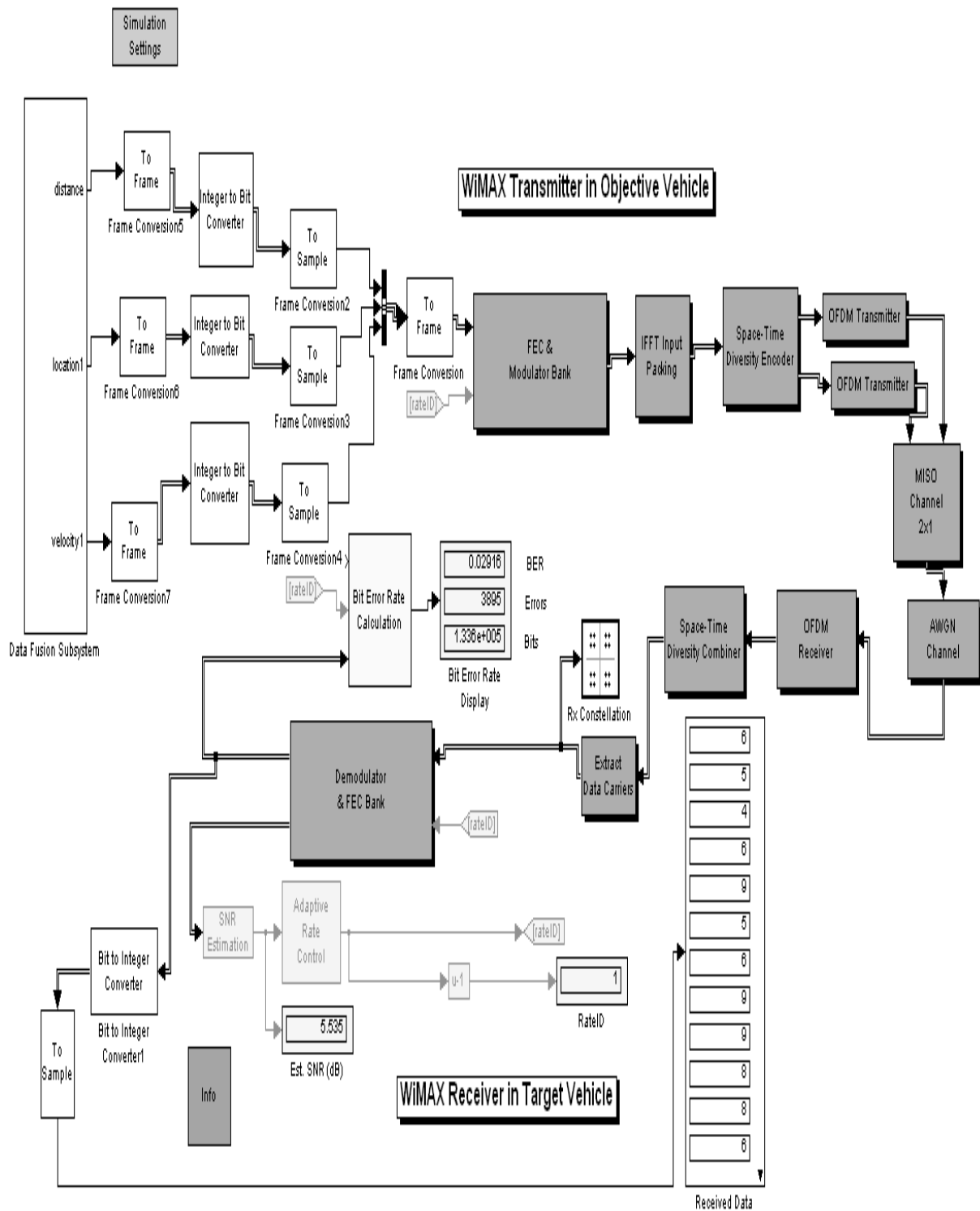
Fig. 12: IVL using WiMA