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# Enabling Seamless V2I Communications

## Towards Developing Cooperative Automotive Applications in VANET Systems

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Cooperative applications for VANET will require seamless communication between Vehicle to Infrastructure and Vehicle to Vehicle. IEEE 802.11p has been developed to facilitate this effort. However, in order to have seamless communication for these applications, it is necessary to look at handover as vehicles move between Road-side Units. Traditional models of handover used in normal mobile environments are unable to cope with the high velocity of the vehicle and the relatively small area of coverage with regard to vehicular environments. The Y-Comm framework has yielded techniques to calculate the Time Before Vertical Handover and the Network Dwell Time for any given network topology. Furthermore, by knowing these two parameters, it is also possible to improve channel allocation and resource management in network infrastructure such as base-stations, relays, etc. In this article we explain our overall approach by describing the VANET Testbed and show that in Vehicular environments it is necessary to consider a new handover model which is based on a probabilistic rather than a fixed coverage approach. Finally, we show a new performance model for proactive handover which is then compared with traditional approaches.

**Keywords**-IEEE 802.11p, VANET, Vehicle to Infrastructure Communication, Time Before Vertical Handover, Network Dwell Time, Proactive Handover, Proactive Resource Allocation, Simulation, Network Performance.

### INTRODUCTION

**S**EAMLESS interoperability in highly mobile environments, such as Vehicular Ad Hoc Networks (VANET) is vital in order to develop cooperative applications that can make full use of networking infrastructure. Traditional handover policies have been based on a reactive approach in which the Mobile Node (MN) reacts to signalling indicating changes in network connectivity as the MN moves around. However, in highly mobile environments with small cell coverage such an approach can quickly lead to degradation of connections due to the small time there is to effect a handover.

Proactive handover in which the MN actively attempts to decide when and where to handover can help to develop an efficient and reliable handover policy mechanism. By using proactive handover, it is possible to minimize packet loss and service disruption as an impending handover can be signalled to the higher layers of the network protocol stack [1]. Two key parameters are used to develop algorithms for proactive handover: Time Before Vertical Handover (TBVH) which is the time after which the handover should occur, and Network Dwell Time (NDT) which is the time the MN spends in the coverage of the new network.

The Y-Comm research effort has defined two types of proactive handover. The first is knowledge-based and attempts to know, by measuring beforehand, the signal strengths of available wireless networks over a given area such as a city. This could involve physically driving around and taking these readings. The second proactive policy is based on a mathematical model which calculates the point when handover should occur and the time that the mobile would take to reach that point based on its velocity and direction [1].

In order to develop a useful model for real networks, it is necessary to accurately model the underlying communication mechanisms and hence, simulation based on the measurements from a real testbed is essential. Therefore, we have designed a new VANET Testbed at the Hendon campus of Middlesex University, London which is currently being fully deployed. This testbed will also provide us with better physical layer and propagation models, so that handover can be optimized. This is because in highly mobile environments it is necessary to have a more exact knowledge of the communication environment including knowing when a beacon can be reliably received when entering a new network. Such information will allow better management of the handover process but will require a new probabilistic approach which is outlined in this article.

A novel aspect in the provision of seamless proactive handover is the design and development of proactive resource allocation techniques. The concept of Proactive Channel Allocation is introduced in this work using TBVH and NDT, but applied to the opportunity of the MN to acquire a channel. These two parameters allow us to determine the times when different nodes will need to acquire and release channels due to mobility. Hence it is possible to explore periods of contention which, in turn, will allow us to develop heuristic algorithms to optimise the use of the channel.

A major area of application of proactive resource allocation is in the area of Intelligent Transport Systems (ITS) using VANETs. Characteristics of VANETs such as high velocity, smaller coverage range and mobility patterns are serious challenges in providing seamless handover, resource allocation and in moving the services from the previous Road-side Unit (RSU) to the new RSU. Therefore developing proactive handover and resource allocation models for VANET systems would be the best option to develop a reliable framework for cooperative applications.

Another interesting area is in the management of Heterogeneous Networking (HetNet) environments using small cells, because their use is considered a promising strategy to cope

with the explosion in mobile traffic. However, the signalling load on the network nodes might increase due to frequent handovers and mobility robustness may be degraded due to increased handover failures and radio link failures [2]. This frequent handover failure can be addressed through proactive handover and resource allocation.

### VANET Testbed at Middlesex University

This article presents a realtime VANET testbed which is being used to develop propagation models to gain a better understanding of the relationship between communication and mobility in a given physical space. This is necessary to accurately predict TBVH and NDT in order to develop Proactive Handover mechanisms. In addition, a probabilistic handover approach is presented based on Cumulative Probability (CP) using the Veins framework in the OMNeT++, which is a discrete event simulation environment. Finally we present preliminary results to show the benefits of proactive handover on overall system performance.

A VANET testbed is currently being fully deployed at the Hendon Campus, Middlesex University, London with four RSUs as shown in the Figure 1. The RSU and the On-board Unit's (OBU) were manufactured by ARADA Systems with the IEEE 802.11p (Wireless Access in Vehicular Environment - WAVE) standard specifications. Three RSUs were deployed on top of three buildings at varying heights, in which two were deployed to cover the roads around the campus and another one is used to support the movement of pedestrians within the campus, hence enabling the development of Vehicle to Pedestrian (V2P) applications. The fourth was deployed around the car park area. Initial testing was carried out to measure the coverage of the deployment by using an OBU, moving around the university roads and inside of the campus. The power received was noted for every 10 meters and represented as numbered dots as shown in the Figure 1(b). In order to explore

the path loss models with real test results, as an initial work, the power received was compared with the Free Space Path Loss (FSPL). This effort was to understand the differences between the theoretical FSPL and measured values. These results indicate that more sophisticated propagation models such as terrain or finite element propagation models need to be developed. This detailed model will allow us to more accurately calculate TBVH and NDT for any given scenario.

### HANDOVER POLICY BASED ON CUMULATIVE PROBABILITY APPROACH

Handover in mobile environments can be depicted as shown in Figure 2(a). There is a hard handover threshold circle depicted by hard barrier and there is a dotted circle within the hard barrier representing the exit threshold. The exit threshold circle is the boundary to start the handover in order to finish the handover before reaching the hard barrier, which is needed for a successful soft handover. If the handover is not successful before the hard barrier then there is a break in the communication which leads to a hard handover. Though this approach is currently being used for mobile communications, in highly mobile environments such as VANETs it presents two challenges: firstly, the exit radius is dependent on the velocity of the MN and hence at high velocities there will be no time to do a soft handover. Secondly, the hard or fixed handover circle represents the area of coverage but at this outer region, actual communication is difficult due to the probability of packets been received with error due to low Signal to Noise (SNR) ratio. Hence a more probabilistic approach is required which makes use of Cumulative Probability to provide a realistic boundary for handover.

Let the probability ( $P$ ) represent the probability of a successful reception of beacon at the Physical (PHY) layer. This probability can be calculated for each beacon with the knowledge of the SNR and the length of the beacon [3],

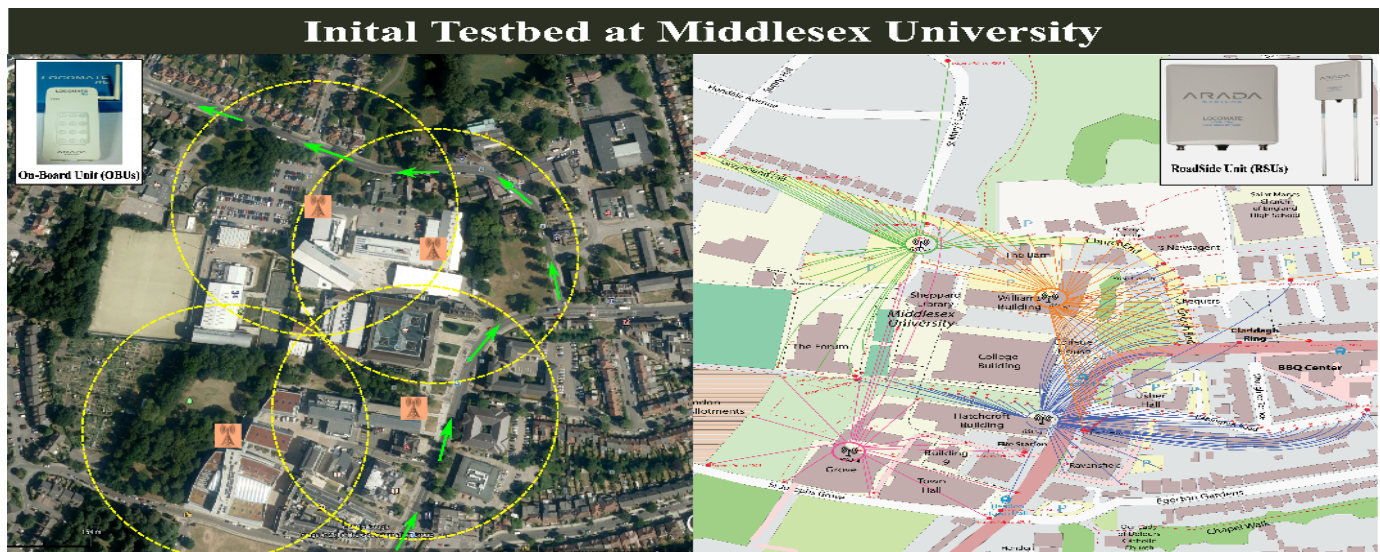


Fig. 1(a) Satellite View

Fig. 1(b) Map View

Fig. 1: MDX-VANET TESTBED

[4]. In probability theory,  $P$  has a stationary distribution i.e., the possible outcomes are constant over time. Hence, we can define the Cumulative Probability as the probability of the event occurring - in this case, a successful beacon reception - before a given time or sequence number. In addition, when  $CP$  is 1, then we are sure that the event has occurred. If  $P$  is constant, then  $CP$  is normally 1 at infinity. In this case however,  $P$  does not have a stationary distribution because as the MN moves towards the RSU,  $P$  increases significantly and hence,  $CP$  will become 1 long before infinity and, in fact, may become 1 before  $P$  becomes 1. Hence this shows that we can be certain of receiving a successful transmission before  $P$  becomes 1 due to  $CP$ . This means that it is necessary to use the  $CP$  approach to determine the regions of reliable communication. Therefore, we need to calculate  $CP$  for a sequence of  $N$  beacon receptions and compare it to when  $P$  is 1.

We define, the  $CP$  as the vehicle enters a new network as the Cumulative Entrance Probability ( $CP_{EN}$ ). For Exit scenarios, we consider the probability of not receiving the beacon  $P_n$  from the RSU as we drive away i.e., the Exit Cumulative Probability, ( $CP_{EX}$ ). For the Exit side,  $P$  the probability of the successful reception decreases as we move away from the RSU, hence  $1-P$  is increasing. Our results therefore considers the effect of the cumulative frequencies on entrance and exit regions of RSU coverage.

Figure 2(b) presents the communication time between the segments or regions named as  $Reg_1$ ,  $Reg_2$ ,  $Reg_3$ ,  $Reg_4$  &  $Reg_5$ . These regions are the communication times i.e., the time duration when beacons are received by the vehicle in a particular segment of RSU coverage.

- $Reg_1$ : Is the region between the first beacon being heard in the PHY layer and the point when  $CP_{EN}=1$ .
- $Reg_2$ : Is the region between  $CP_{EN}=1$  and the point where  $P$  is first equal to 1.
- $Reg_3$ : Is the region where  $P$  is always equal to 1.
- $Reg_4$ : Is the region between the last beacon where  $P = 1$  and  $CP_{EX}=1$
- $Reg_5$ : Is the region between  $CP_{EX}=1$  and the last beacon being heard at the PHY layer for that RSU.

In order to explore these concepts, a simulation was carried out with one RSU and one vehicle moving along the road using Veins Framework in OMNeT++. The Framework supports IEEE 802.11p and the coverage radius of the RSU was 907m with 20mW transmission power and the minimum receiver gain was set to -94 dBm [5]. For the simulation two different velocities were considered, 10 m/s (i.e.,36km/h) for urban speed and 30 m/s (i.e.,108km/h) for motorway speed. The results in [6] also showed that for handover, a maximum beacon size between approximately 600 to 800 bytes could give the best chance for seamless communication. Hence, beacon sizes of 300, 500 and 723 bytes have been considered to conduct our study. In addition to this, the work in [6] also showed that an ideal range of beacon frequency for vehicular communication is between 10 to 20 Hz. Hence beacon frequencies of 10, 15 and 20 Hz are considered in this article. When there is an increase in beacon frequency,

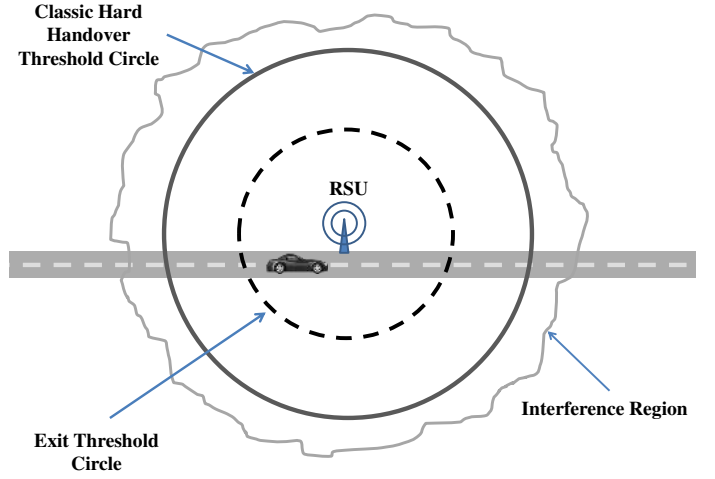


Fig. 2(a)

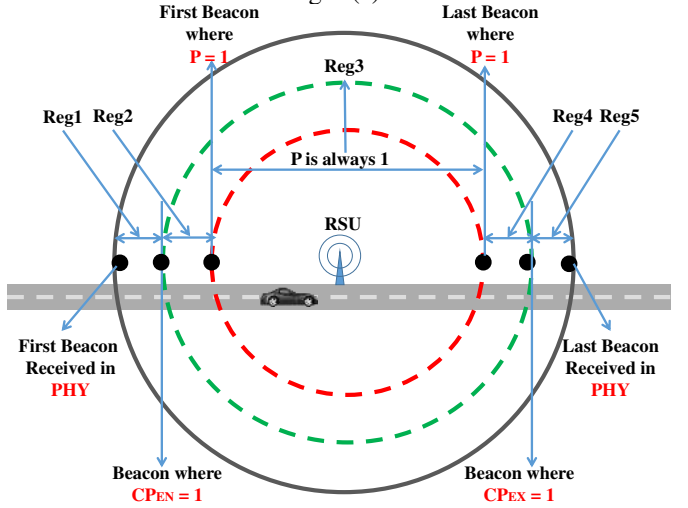


Fig. 2(b)

Fig. 2: Traditional and Probabilistic Segmentation.

a considerable amount of communication time is achieved between  $CP_{EN} = 1$  and  $P = 1$  (i.e.  $Reg_2$ ) and between  $CP_{EX} = 1$  and  $P = 0$  (i.e.  $Reg_5$ ). This clearly indicates that a high beacon frequency should result in an increased NDT as the beacon is heard almost as soon the vehicle enters the coverage area.

#### ANALYSIS OF OVERLAPPING REGION

In order to verify our handover policy based on the  $CP$  approach, we have come up with three different scenarios of overlapping two RSUs as shown in Figure 3. A mobile node (i.e. in our case a vehicle) is made to travel over the coverage range of these two RSUs with velocities of 10 m/s and 30 m/s for collecting various values for our study. The same parameter settings were used as done for the one RSU simulation experiment setup for calculating  $CP$ .

**Case (i)** The two RSUs are overlapped such that RSU 1's last beacon received by the vehicle with  $P = 1$  and RSU 2's first beacon with  $P = 1$  are received one after another. The



time difference between these two beacons is very small and hence the Figure 3 shows these two beacons at the same point.

**Case (ii)** The two RSUs are overlapped such that RSU 1's last beacon with  $P = 1$  and RSU 2's first beacon reaching  $CP_{EN} = 1$  are received one after another.

**Case (iii)** The two RSUs are overlapped such that RSU 1's beacon reaching  $CP_{EX} = 1$  and RSU 2's beacon reaching  $CP_{EN} = 1$  are received one after another.

The simulation results for each case are illustrated as graphs in Figure 3. In Case (i) as mentioned earlier the overlapping of two RSUs are setup such that  $P$  is 1 for both RSUs at the overlapping region. Hence it is clearly evident from the graph that once the vehicle reaches the region where  $P = 1$  of RSU 1, there is no drop in  $P$  till the vehicle exits the RSU2's  $P = 1$  region, i.e.  $P$  is always 1 as shown in Figure 3. From this observation it is clear that, this is the most reliable way of overlapping adjacent RSUs which ensures seamless handover. But this reliability comes at the cost of more overlapping distance as shown in the graph in Figure 3 and high interference issues as indicated in [7] as both RSUs are in communication range of each other.

In Case (ii) as the RSUs are setup such that of RSU 1's last beacon with  $P = 1$  and  $CP_{EN}$  of RSU2 is 1 at the overlapping region. This way of overlapping yields us less overlapping distance as shown in Figure 3 compared to case (i), however there is a very negligible amount of drop in  $P$  at the overlapping region i.e.,  $0.99 < P < 1$ , Figure 3. According to [8]  $P$  should be greater than 0.99 for the safety related applications. Hence, case (ii) is equally reliable and also

ensures seamless handover.

In Case (iii), the RSUs are setup considering  $CP_{EX}$  of RSU 1 and  $CP_{EN}$  of RSU2 for overlapping. This way of overlapping gives an advantage of a much smaller overlapping distance as compared to cases (i) & (ii). This also benefits the network with less interference as indicated in [7]. In the overlapping region,  $P$  reduces to less than 0.7 which is not suitable for seamless communication or safety critical applications.

As shown above case (ii) performs equally good as case (i), therefore this approach can be adopted for a scenario where critical life-safety application are given higher priority. By contrast, the Case (iii) approach is more suitable for a scenario where optimal coverage is required and where non-safety applications are used.

In addition, the CP approach can be used to improve handover since  $CP_{EN} = 1$  tells us when we are certain to have received at least one beacon from the new RSU. Hence, we should ensure that handover can occur before  $CP_{EN} = 1$ . Similarly,  $CP_{EX} = 1$  indicates when we are sure not to have heard a beacon from the current RSU and hence, we need to ensure that the MN should have been handed over to the next RSU before this point. It is therefore no longer necessary to manage handover using the hard handover circle as this probabilistic approach based on CP should yield more reliable results. Therefore, the CP mechanism should be incorporated into the handover mechanism for MNs.

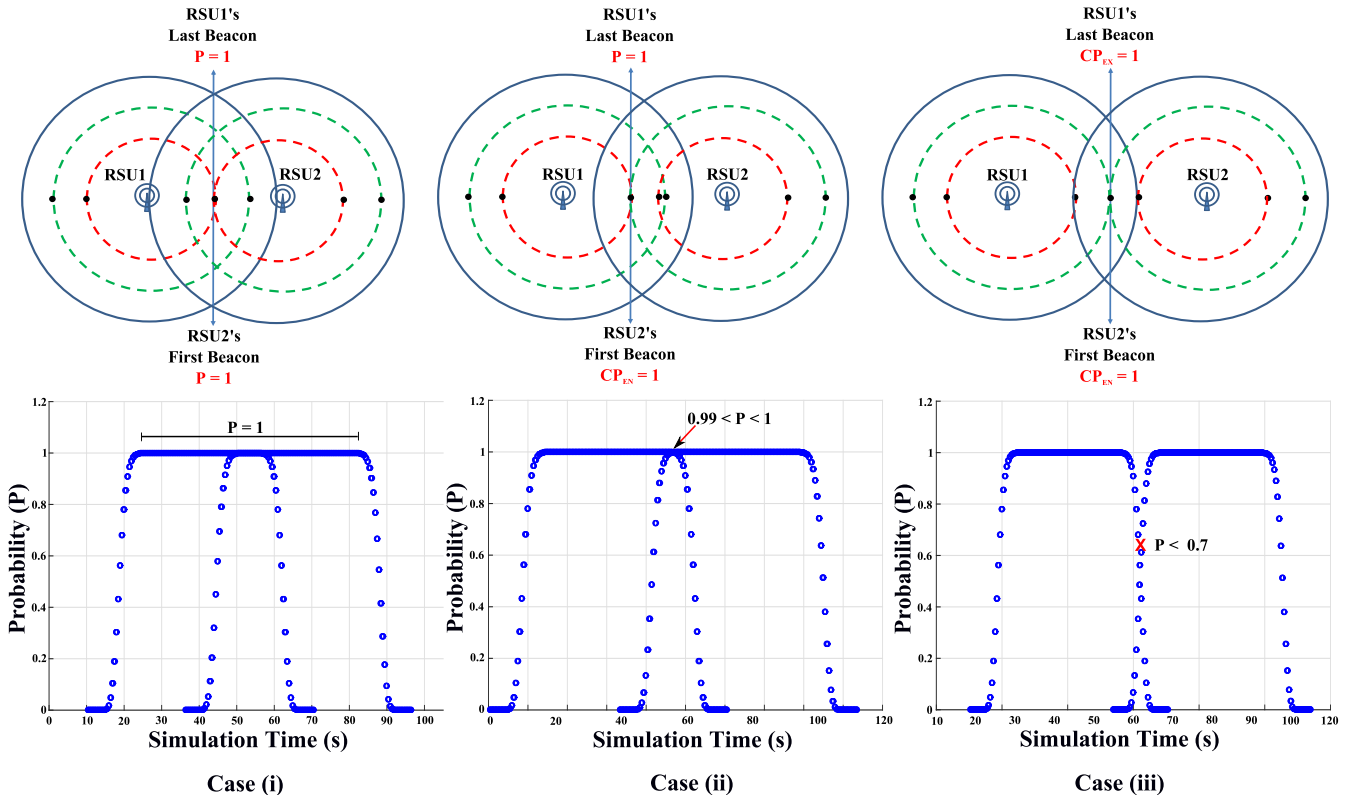


Fig. 3: Overlapping Scenarios

## PROACTIVE CHANNEL ALLOCATION

The probabilistic approach in the previous section allows us to calculate NDT and TBVH more accurately. In this section we use these parameters to explore proactive channel allocation. We will first look into a simple scenario where a network uses a single channel and two MNs are moving at a velocity ( $v$ ) towards that network range as shown in Figure 4.  $MN_A$  and  $MN_B$  can request the channel for communication. Assuming that  $v$  and TBVH are already known,  $t_c$  is the current time at the node and  $NDT_{next}$  is the estimated NDT of the MN in the next network; hence the time when the channel will be needed for communication and when a MN will release the channel due to mobility is as shown below:

- $MN_A$  needs channel at  $(t_c + TBVH)_A$
- $MN_A$  releases the channel at  $(t_c + TBVH + NDT_{next})_A$
- $MN_B$  needs channel at  $(t_c + TBVH)_B$
- $MN_B$  releases the channel at  $(t_c + TBVH + NDT_{next})_B$

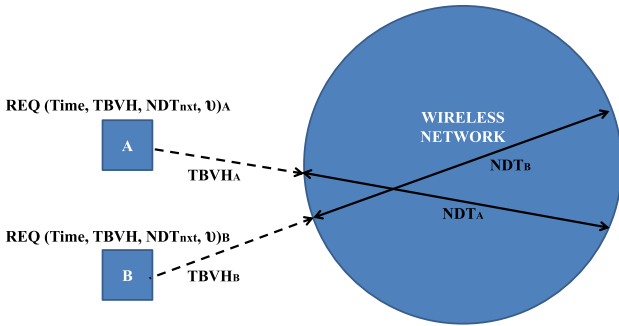


Fig. 4: Request for Channel Allocation

Based on the channel request and holding time of  $MN_A$ , there are three possible contention happening which affects  $MN_B$  in this scenario.

- No Contention
  - The channel release time of  $MN_A$  is less than the channel need time of  $MN_B$ . Hence, there is no contention as  $MN_B$  needs the channel after  $MN_A$  has finished using the channel.
- Partial Contention
  - The channel release time of  $MN_A$  is less than the channel release time of  $MN_B$ . This means that  $MN_A$  uses the channel first. However,  $MN_A$  releases the channel while  $MN_B$  still can use the channel and hence there is partial contention.
- Full Contention
  - The channel release time of  $MN_A$  is greater than the channel release time of  $MN_B$ . In this scenario  $MN_A$  uses the channel and releases the channel after  $MN_B$  no longer needs the channel as  $MN_B$  has moved out of the range of the network. Hence,  $MN_B$  never gets access to the channel, this is called full contention.

### Impact of full contention

In the event of a full contention,  $MN_B$  will not get the channel from the next network range. If this total contention

can be identified and notified before  $MN_B$  reaches the next network range, then the contention can be signalled to  $MN_B$  and  $MN_B$  can therefore use other available communication technology instead of waiting for the channel which is never available. For no or partial contention,  $MN_B$  can be signalled that it will get to use the channel and hence can queue for service. This approach should result in better network performance.

## PROACTIVE QUEUING APPROACH FOR HANDOVER IN MOBILE ENVIRONMENTS

In this section we consider a simple scenario to explore the new proactive handover mechanism. In classic soft handover the MN will be placed in the queue to be served as shown in Figure 5, i.e., waiting for the channel to get an opportunity to communicate. This queuing model is commonly used to analyse mobile networks [9]. The Server, in this case, the channel mechanism, uses a First in, First out, (FIFO) service discipline and requests are placed in the queue if the server is busy. Since the MNs are moving at a velocity and waiting for the channel, there is a probability that the MN will not get a channel due to mobility. For the MN that is being served, there is a possibility that it can also leave the network partially served due to mobility. Therefore, the rate at which the MN might leave the system due to mobility is denoted as  $\mu_m$ .  $\lambda$  is the arrival rate of the request.  $\mu_s$  is the rate at which the requests are being served. Thus the overall service rate i.e., the rate at which mobile nodes leave this network varies as any MN may leave the queue without being served.

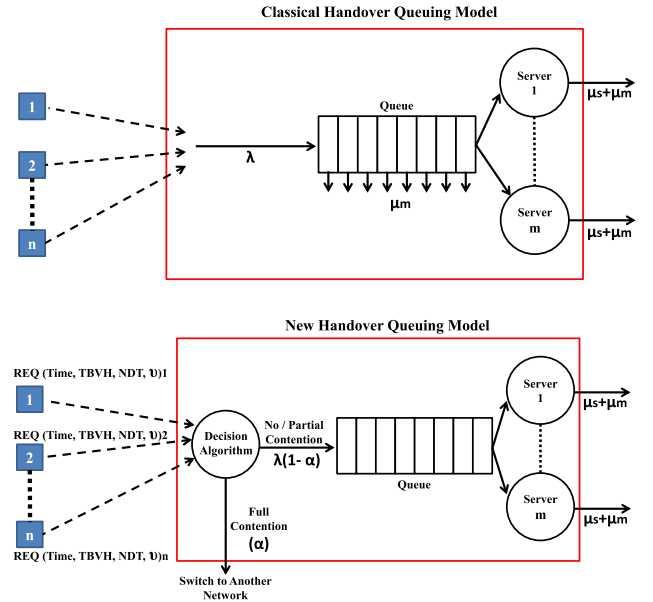


Fig. 5: Classical and Proactive Handover Multi Channel Queuing System

In our proactive approach also shown in Figure 5, the decision algorithm based on the contention analysis as described above will decide whether the node will be admitted to the queue. This ensures that nodes do not wait unnecessarily and leave the queue unserved because of mobility. Thus all channel

requests allowed into the queue will eventually be served so the requests in the queue will not leave the queue due to mobility. However, only the request that is being served can leave the system due to mobility. Hence the service rate is  $\mu_s + \mu_m$ .

We define  $\alpha$  as the percentage of calls dropped due to contention. For the purpose of our analytical model we assume that  $\alpha$  is constant. It is assumed that the rejected request time in the system is zero. Since requests are rejected from entering the queue due to contention, the arrival rate is  $\lambda(1 - \alpha)$ . If  $\alpha$  is independent of  $(\mu_s + \mu_m)$  the queue can be treated as a normal M/M/1/K where K is the maximum number of packets in system.

The key parameters used in comparing the two models were the use of two servers and a velocity of 30m/s. We assume a mixed traffic pattern where on average a minimum of 2 slots of 0.5 milliseconds as in LTE and described in [10]. Therefore we use a conservative value of a service rate  $\mu_s$  of 4000 packets/s. The analytical results for both the classic and proactive handover approach using a two channel system are presented as graphs in Figure 6 for the velocity 30 m/s. The graphs clearly show that the proactive approach works far better than the classic approach in terms of Blocking probability ( $p_B$ ) and Mean No. of Jobs (N).

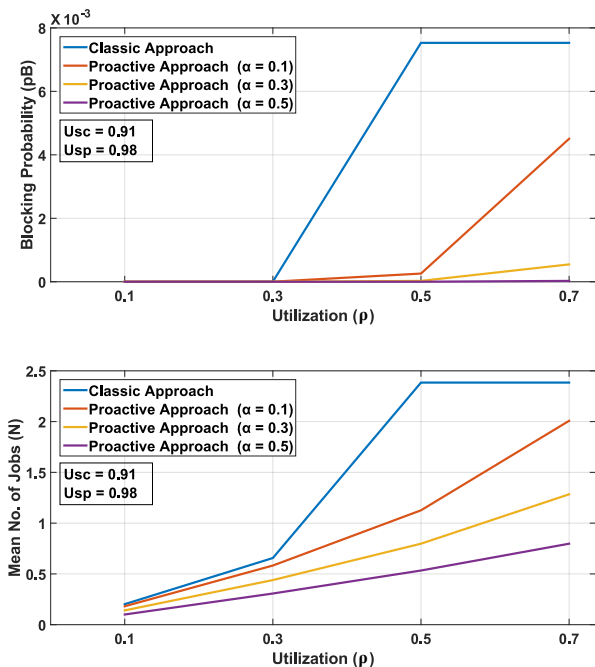


Fig. 6: Two Server: Classical vs Proactive Approach (30m/s)

## CONCLUSION

In this article we have presented a new VANET Testbed which is being deployed at Middlesex University, London. In addition, we have shown that to accurately calculate useful values of TBVH and NDT, a probabilistic approach based on

accurate propagation models from a real testbed is required. It has been shown how the Cumulative Probability approach is a better mechanism for estimating these values. Furthermore, based on realistic TBVH and NDT values it has been shown how these can be used for proactive channel allocation.

## AUTHOR INFORMATION

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