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A Novel Approach to Compute the Handover Probabilities based on Mobility in WPAN

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Abstract- A novel approach has been presented to compute the probabilities of unsuccessful handovers based number of free channels available in the target AP and number of free channels available plus based on the mobility of mobile device. The number of free channels in the AP is 16 and the mobility of the mobile device in the 8 different directions is considered. The directions of movement are 0, 45, 90, 135, 180, 215, 270 and 315 that a mobile can take a turn to. If the mobile device is handed over to the target AP based on the movement of the mobile device, then the proposed model can be used to compute the probabilities of the unsuccessful handover if the number of free channels in the target AP is different than expected with respect to the host AP. The probabilities of the incorrect decision is plotted for the cases of mobile device moving in a direction normal to the boundary and moving along the boundary are plotted.

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A Novel Approach to Compute the Handover Probabilities based on Mobility in WPAN

Ch.Subrahmanyam [α] & K. Channakesavareddy [σ]

Abstract- A novel approach has been presented to compute the probabilities of unsuccessful handovers based number of free channels available in the target AP and number of free channels available plus based on the mobility of mobile device. The number of free channels in the AP is 16 and the mobility of the mobile device in the 8 different directions is considered. The directions of movement are 0, 45, 90, 135, 180, 215, 270 and 315 that a mobile can take a turn to. If the mobile device is handed over to the target AP based on the movement of the mobile device, then the proposed model can be used to compute the probabilities of the unsuccessful handover if the number of free channels in the target AP is different than expected with respect to the host AP. The probabilities of the incorrect decision is plotted for the cases of mobile device moving in a direction normal to the boundary and moving along the boundary are plotted.

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I. Introduction

Mobility of the mobile devices plays an important role in the handover. When the mobile devices are stationary with respect to the access points (AP), then it is easy for the network to decide where the mobile device needed to be handed over to. For example, the mobile devices can be handed over to the nearest AP. Again the handover is based on several criteria like available bandwidth [1], received signal strength [2,3], Bit error rate, mobility etc[4]. Handovers based on the mobility are very important compared to all other parameters. The mobility based handovers are very popular in the wireless networks [4]. The mobility may be defined as the movement of the mobile device in a certain direction and the handover is initiated based on the location of the mobile device after certain interval of time. It may be possible that handover is initiated assuming that the mobile device will be there in the service zone of the next AP, but eventually the mobile device will not arrive into that service zone since mobile device has changed the direction of its movement in the mean time.

Mobility based handovers were analyzed by some researchers [4] for the wireless communications. The performances of various algorithms were discussed in ref [5]. A survey was conducted by Camp et.al on the subject of the mobility based handovers in the wireless networks [6]. Vijayan et.al developed models to compare the performance of the handover algorithms [5]. However there was a limitation in this approach that the model has limited application to heterogeneous networks.

The problem of type network such as homogenous, heterogeneous, horizontal or vertical networks was overcome by the model proposed by Chi .et. al [1]. The unsuccessful handover were analyzed by the Chi et.al for the two node wireless network models, but based on the band width. Authors have extended the models to a generalized model for 2, 3, 4 and 5 node networks for WPAN/WLAN environment [7]. It was discussed in [7] about how the unsuccessful handover probability models can be extended to the WPAN/WLAN environment. Also a common approach has been proposed in [7] on how to select a set of APs depending up on the location of the mobile device.

Akhila et. al [3,4] developed a model for the handovers in the wireless environment. However, the model proposed by Akhila et.al focused on the handovers based on mobility only [4]. It did not focus on the combined effect of mobility and the band width together, since, if the handover is initiated based on the direction of movement, and enough bandwidth is not available when the actual transfer happens in the target AP, then it becomes an unsuccessful handover. In this work, a generalized handover model that was developed as part of the work by authors [7] is extended to mobility based handover also. That is, the proposed model considers 2-AP, 3-AP, 4-AP and 5-AP models, with free bandwidth and with free bandwidth plus mobility. This model is more realistic for hospital environment as the proposed model involves WPAN application, different AP models, fee channels and mobility based handovers. Other handover algorithms are developed by various researchers that can be found in [8-12].

In Sec.II, physical model and handover approach in a hospital environment has been developed. In Sec.III, the generalized probability model that has been developed in [7] is extended to consider the mobility also. In Sec IV, the models were run and simulation results are discussed for 2-AP, 3-AP, 4-AP and 5-AP models by solving the probabilities equations presented in Sec. III. The results are presented two cases, when the mobile device was moving normal to

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the boundary and when it was moving along the boundary. The probabilities of unsuccessful handover that has happened unnecessarily, probability of handover that has missed to happen and total probability of unsuccessful handover due to incorrect decision are presented for the two cases. Finally, important conclusions are drawn in Conclusions section.

II. Physical Model and Handover Approach

Fig.1 shows a hospital that has several rooms open to the hall area. There is room dedicated for parking the mobile devices that are used for the diagnosis. Also there are other mobile devices in the hall area that are not necessarily used for diagnosis, but devices like laptops, tablets etc. Hence all of these devices along with the diagnosis devices are treated as mobile devices. The devices used for diagnosis purpose are parked in the parking in room when not being used. Also, these devices are electrically charged when they are parked in the parking room. Fig.1 shows the mobile device M1 moving from the Parking Room to Patient Room 2. When M1 is the service zone of AP-NE, the M1 is served by that AP. But when the M1 is crossing the boundary, then the M1 has to be serviced by the nearest AP. For example when the M1 enters the service zone of AP-NW, then it is served by that AP.

Assume that AP-NE has sufficient number of free channels and it is serving M1, then it also understands that the M1 is moving a specific speed and moving towards the AP-NW service zone. This is understood by the AP-NE, by exchanging the singles frequently with M1. By getting the time interval of the received signals from M1, the AP-NE calculates the location coordinates of M1, direction of movement as well as its speed of movement. Based on the speed of movement and direction of movement, AP-NE initiates a hand over of M1 to AP-NW when it is at the boundary of the AP-NE service zone. The handover may be treated as successful if AP-NW has sufficient number of free channels as well as the number of free channels in the AP-NW is higher than the AP-NE. If the number of free channels in AP-NW is less than the AP-NE, the handover is considered as unsuccessful. If the AP-NW does not have any free channels at all when the handover takes place, the M1 is becomes an orphan node and the connection is lost. This is known as unsuccessful handover that happened unnecessarily. The AP-NE might have continued to serve the M1 while it is in AP-NW zone since the number of free channels in AP-NE is more than that of AP-NE.

Other possibility is, when the decision is taken to handover the M1, the AP-NE checks the number of free channels available in AP-NW. if the number of free channels in AP-NW is less than that in AP-NE, the AP-NE does not handover the M1 to AP-NW, but, M1 continues to move into the AP-NW zone.

The M1 moves from parking room (AP-NE zone) to patient room 2 (AP-NW zone). Then from patient room 2 to radiology lab 1, that is from AP-NW zone through AP-C zone to AP-NE zone. Path 3 shows the M1 moving from radiology lab 2 to ICU-1 and then from ICU-1 to parking room. Depending upon the location of the mobile device, there is possibility of handover taking place to the nearest access point. The AP model to be chosen for handover is given in ref [7].

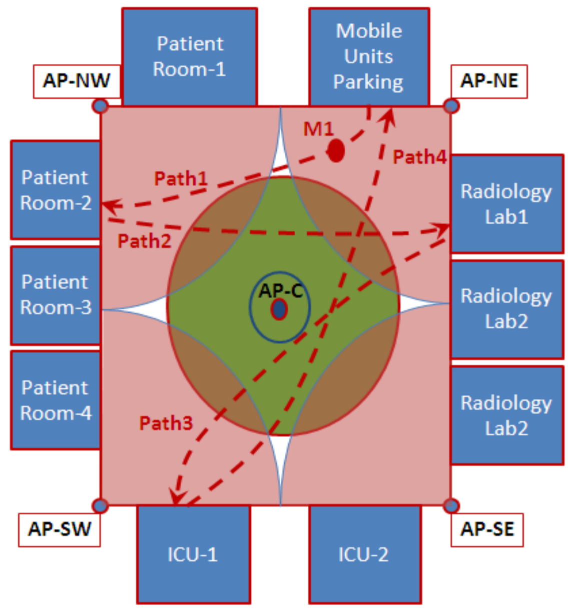

Figure 1 : A hospital hall area with a mobile device M1 moving around the hall

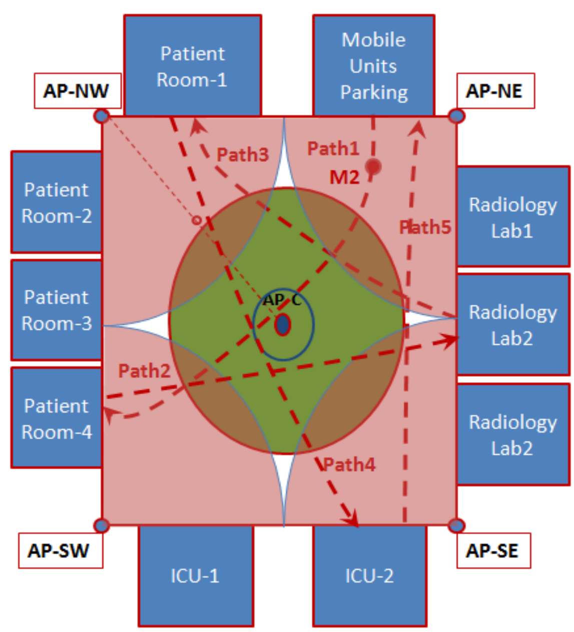

Figure 2 : A hospital hall area with a mobile device M2 moving around the hall

Fig. 2 shows another case of the paths followed by the mobile device M2. In this case, when path 5 is carefully observed, the path 5 is almost tangential to the service zone of AP-C. If the handover happens to AP-C from AP-SE, then it is a handover that happened unnecessarily. But f is just inside the AP-C zone, then another handover has to happen immediately since the M2 is moving to the zone of AP-NE. Hence based on the speed and direction of movement, the handover can be delayed to prevent handovers happening unnecessarily.

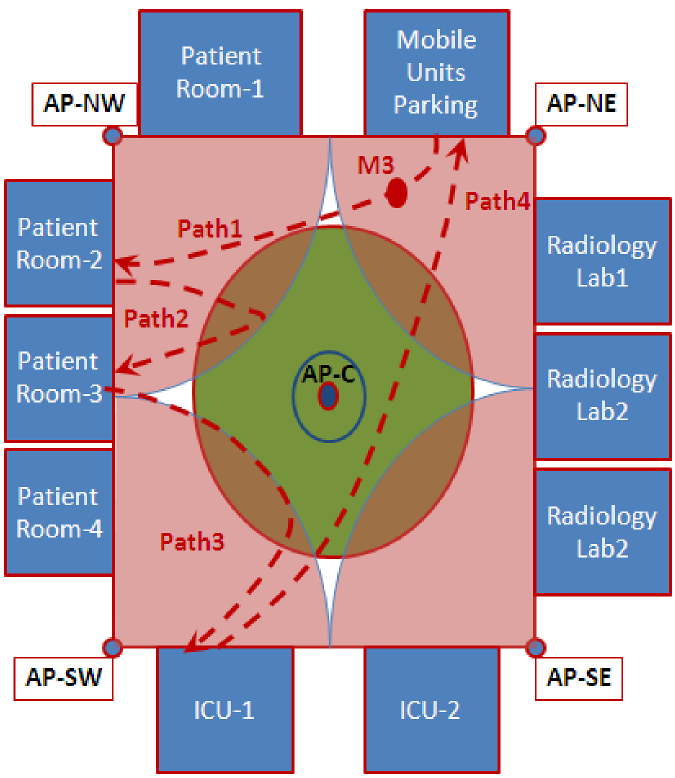

Figure 3 : A hospital hall area with a mobile device M3 moving around the hall

Fig.3 shows the movement of mobile device M3 in 4 paths. Path 2hsoews that M2 moved from patient room 2 towards the boundary of the AP-NW. Based on the direction and speed of movement, the handover happens from AP-NW to AP-C. But it changes its direction back into the AP-NW zone without actual crossing into AP-C. Hence the handover happened here again unnecessarily. A slight delay in decision making would bring reduction in unnecessary handovers, in this case also.

Path3 is very peculiar since the movement is along the boundary of the AP-SW zone. Here depending up on the location of M3 with respect to the boundary, the M3 can be either in AP-SW zone or in AP-C zone or it can move back and forth into and out of these two zones. Hence the handover has to happen frequently when M3 is moving along this path.

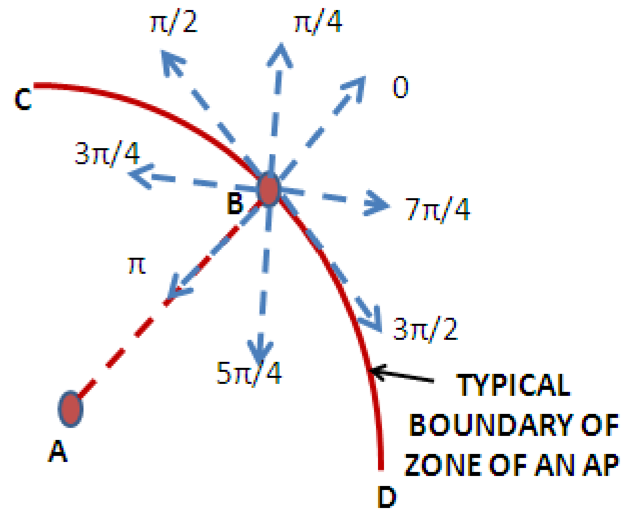

Figure 4 : Movement vectors with respect to a typical boundary when mobile device moving normal to the boundary

III. Probability Model

Fig. 4 shows the vectors representing the direction of the movement. Initially the mobile device is inside the service zone is at point A and then starts moving towards point B. The arc CBD represents a typical boundary of the service zone of an AP. When the mobile device is inside the arc CBD, then the AP serves the mobile device. When it is outside the arc CBD, then the mobile device is served by another nearest AP after successful handover. In Fig.4, relative vectors shown at point B. The mobile device that has reached point B can continue its movement in the same direction which is 0radians. The angles are defined with respect to its present movement. The mobile device can take left turns at $\pi/4$ or $\pi/2$. Or it can take the right turns at $3\pi/2$ or $7\pi/4$. In all these cases of 0, $\pi/4$, $\pi/2$, $3\pi/2$ or $7\pi/4$ the mobile node location is outside the arc CBD, and hence needed to be handed over to the nearest AP. If the mobile device takes turns at angles $3\pi/4$, π or $5\pi/4$, the mobile device needed to be retained with the same AP. The probabilities of the mobile device moving in the directions of angle

$$P_{\theta_i} = P_0 \frac{1}{\sigma_{\theta_i}\sqrt{2\pi}} e^{\frac{\theta_i^2}{2\sigma^2_\theta}} + P_{\pi/4} \frac{1}{\sigma_{\theta_i}\sqrt{2\pi}} e^{\frac{\left(\theta_i - \frac{\pi}{4}\right)^2}{2\sigma^2_\theta}} +$$

$$P_{\pi/2} \frac{1}{\sigma_{\theta_i}\sqrt{2\pi}} e^{\frac{\left(\theta_i - \frac{\pi}{2}\right)^2}{2\sigma^2_\theta}} + P_{3\pi/4} \frac{1}{\sigma_{\theta_i}\sqrt{2\pi}} e^{\frac{\left(\theta_i - \frac{3\pi}{4}\right)^2}{2\sigma^2_\theta}}$$

$$+P_{\pi}\frac{1}{\sigma_{\theta_i}\sqrt{2\pi}}e^{\frac{(\theta_i-\pi)^2}{2\sigma^2{}_{\theta}}}+P_{5\pi/4}\frac{1}{\sigma_{\theta_i}\sqrt{2\pi}}e^{\frac{\left(\theta_i-\frac{5\pi}{4}\right)^2}{2\sigma^2{}_{\theta}}}$$

$$+_{3\pi/2}\frac{1}{\sigma_{\theta_i}\sqrt{2\pi}}e^{\frac{\left(\theta_i-\frac{3\pi}{2}\right)^2}{2\sigma^2{}_{\theta}}}+P_{7\pi/4}\frac{1}{\sigma_{\theta_i}\sqrt{2\pi}}e^{\frac{\left(\theta_i-\frac{7\pi}{4}\right)^2}{2\sigma^2{}_{\theta}}} \quad (1)$$

Where P_{θ_i} the relative is change in direction at the junction and $P_{\pi/4}$ are the probabilities of the mobile device moving in the direction of $\pi/4$. $P_{\pi/4}$ is obtained from the historical data. When a Mobile device is on the arc CBD, handover is initiated assuming that the Mobile device will enter into the service zone of the next available nearest APs. But if it does not move into that zone, then the handover has happened unnecessarily. Therefore the probability of the handover that has happened unnecessarily is given by

$$P_{hu-mob}=P\left(\frac{3\pi}{4}\right)+P(\pi)+P\left(\frac{5\pi}{4}\right) \quad (2)$$

When a Mobile device is just inside or on the arc CBD, handover is not initiated assuming that the Mobile device will remain in the service zone of the same AP. But if it moves into the next zone during the decision time, then the handover has missed to happen. Therefore the probability of the handover that has missed to happen is given by

$$P_{hm-mob}=P\left(\frac{3\pi}{2}\right)+P\left(\frac{7\pi}{4}\right)+P(0)+P\left(\frac{\pi}{4}\right)+P\left(\frac{\pi}{2}\right) \quad (3)$$

Similarly when the mobile device is initially at point D and is moving along the arc DBC towards point B. At point B, the mobile device can take a turn into any of the eight available turns. Handover is initiated assuming that the mobile device is moved into any of the turns at 0, $7\pi/4$, $3\pi/2$, $5\pi/4$ or π while it actually takes a turn to any of the angles $\pi/4$, $\pi/2$, or $3\pi/4$. Then the handover happens unnecessarily. Therefore the probability of the handover that has happened unnecessarily is given by

$$P_{hu-mob}=P\left(\frac{\pi}{4}\right)+P\left(\frac{\pi}{2}\right)+P\left(\frac{3\pi}{4}\right) \quad (4)$$

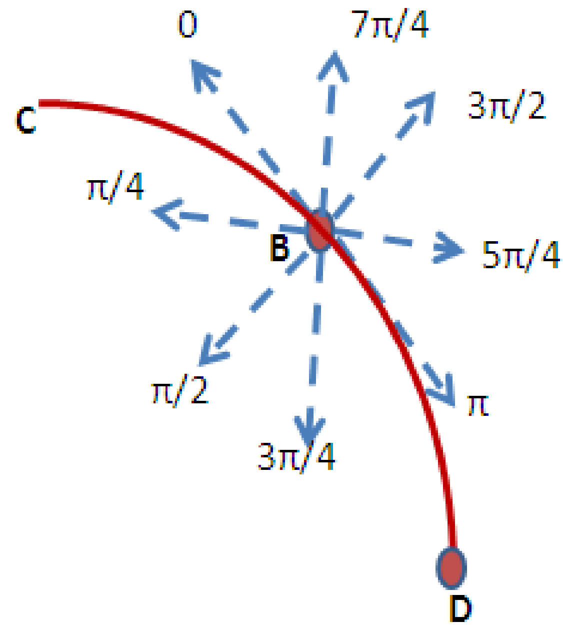

Figure 5 : Movement vectors with respect to a typical boundary when mobile device moving along the boundary

If handover is not initiated assuming that the mobile device is moved into any of the turns at $\pi/4$, $\pi/2$, or $3\pi/4$ while it actually takes a turn to any of the angles 0, $7\pi/4$, $3\pi/2$, $5\pi/4$ or π. Then the handover has missed to happen. Therefore the probability of the handover that has missed to is given by

$$P_{hm-mob}=P(0)+P\left(\frac{7\pi}{4}\right)+P\left(\frac{3\pi}{2}\right)+P\left(\frac{5\pi}{4}\right)+P(\pi) \quad (5)$$

The probability of handover that happened unnecessarily and that has missed to happen based on the availability of free channels in the target AP are given by

$$P_{hu-chn}=\sum_{i=1}^{n}\sum_{\substack{j=1\\ j\neq i}}^{n}P_iP_{j/i}\sum_{m=X}^{A_j}\Pi_{j,A_j-m}\sum_{k=0}^{m-X}\Pi_{i,A_i-k}\Omega_i(k,r,t)$$

$$\bullet\sum_{n=0}^{A_i}\Pi_{i,A_i-n}\sum_{k=n+X}^{A_j}\Pi_{j,A_j-k}\Phi_j(k,r,t)$$

$$P_{hm-chn}=\sum_{i=1}^{n}\sum_{\substack{j=1\\ j\neq i}}^{n}P_i\left(1-P_{j/i}\right)\sum_{n=0}^{A_i}\Pi_{i,A_i-n}\sum_{k=0}^{n+X-1}\Pi_{j,A_j-k}\Omega_j(k,r,t)$$

$$\bullet\sum_{m=X-1}^{A_J}\Pi_{j,A_j-m}\sum_{k=m-X+1}^{A_i}\Pi_{i,A_i-k}\Phi_i(k,r,t) \quad (6)$$

Refer to [1,7] for more details about the nomenclature and details about the above two equations.

The total probability of the handover that happened unnecessarily, since the mobile device has been transferred to the next available AP based on the movement of the mobile device, but the number of free channels in the present AP is higher than that in the target AP when the actual transfer happens. Therefore,

$$P_{hu} = P_{hu-mob} * P_{hu-chn} \tag{7}$$

Similarly,

The total probability of the handover that has missed to happen is

$$P_{hm} = P_{hm-mob} * P_{hm-chn} \tag{8}$$

The unsuccessful handover probability due to incorrect decision is given by

$$P_{ush} = P_{hu} + P_{hm} \tag{9}$$

IV. Simulation Results

In this work, simulations are run for the cases of handover probabilities when only bandwidths are considered as criteria for handovers, and bandwidths plus movement of the mobile device are considered as criteria for the handover. Table 1 shows the probabilities for four different case. Each case shows the probabilities for the mobile device moving in certain angles. These probabilities are assumed here for the simulation purpose. However, these probabilities are to be derived from the historical data for each application like hospitals, railway stations, bus stations etc. In case 1, there is probability of 0.1 that a mobile device moves in the same direction (0 degrees). That means, 1 out of 10 mobile devices always moves in the same direction of its approach. Another probability of 0.3 exists at 135 degrees. Similarly there are probabilities defined for 8 different angles for each of four cases.

Table 1: Probabilities of Mobile device taking a turn

	Case 1	Case 2	Case 3	Case 4
P0	0.1	0.5	0.02	0.04
Pπ/4	0.08	0.02	0.06	0.09
Pπ/2	0.05	0.1	0.09	0.02
P3π/4	0.3	0.2	0.4	0.03
Pπ	0.1	0.04	0.1	0.2
P5π/4	0.2	0.09	0.03	0.02
P3π/2	0.08	0.02	0.2	0.1
P7π/4	0.09	0.03	0.1	0.5

Table 2 shows the probabilities that handover happened unnecessarily and that has missed to happen for the cases when the mobile device was moving towards the boundary of the service zone and when the mobile device was moving along the boundary. These probabilities are obtained after solving the equations listed in the last section.

Table 2 : Computed unsuccessful probabilities when handover happened unnecessarily and when handover missed to have happened

	Normal to Boundary		Along Boundary	
	Phu	Phm	Phu	Phm
Case 1	0.4457	0.2538	0.44	0.2493
Case 2	0.4644	0.591	0.5129	0.4134
Case 3	0.3451	0.3641	0.4042	0.1554
Case 4	0.5015	0.4016	0.4566	0.6028

Fig. 6 shows the probability of the handover that has happened unnecessarily for cases with only free channel; and free channel plus mobility care considered as criteria, when the mobile node was moving in the normal direction to the boundary of the service zone and for the case 1 scenario. The 4 different models of 2-AP, 3-AP, 4-AP and 5-AP are run. 2-AP-Chn model is the one where the 2-AP model with free channel availability is considered for the handover criteria. 2-AP-Chn-Mob is the one where the 2-AP model with free channel availability and mobility is considered for the handover criteria. Similarly other models are named in Fig. 6 to 11.

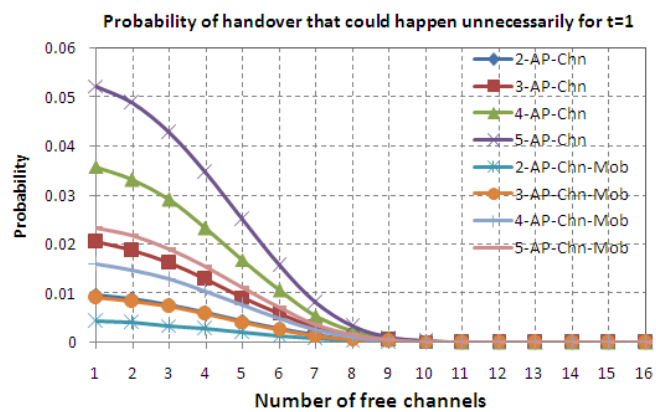

Figure 6 : Probability of the handover that has happened unnecessarily for cases with only free channel and free channel plus mobility considered as criteria

From Fig. 6, it shows that when there is 1 free channel, the unsuccessful handover probability is 5.2% for the 5-AP-Chn model, and it is 2.4% for 5-AP-Chn-Mob model. The probabilities are reduced by 50% when the mobility models are considered. 4-AP-Chn model yielded 3.5% of unsuccessful handover probability that has happened unnecessarily, where as it is 1.6% in 4-AP-Chn-Mob model when the number of free channels available is just one in the target AP.

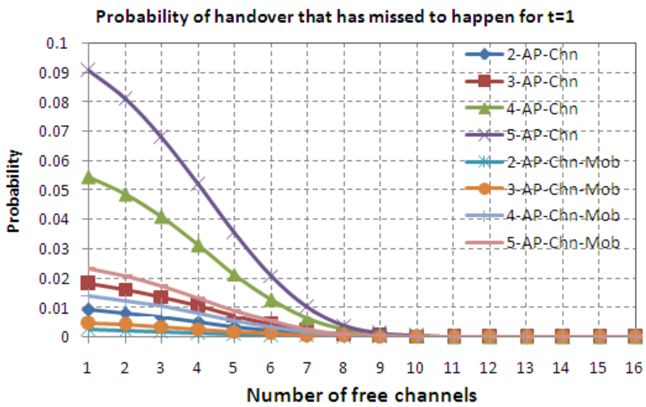

Figure 7 : Probability of the handover that has missed to happen for cases with only free channel and free channel plus mobility considered as criteria

Fig. 7 shows the probability of the handover that has missed to happen. It is clear from Fig.7 that when there is 1 free channel, the unsuccessful handover probability is 1% for the 2-AP-Chn model, and it is 0.3% for 2-AP-Chn-Mob model. The probabilities are reduced by more than 50% when the mobility models are considered. 3-AP-Chn model yielded 1.9% of unsuccessful handover probability that has missed to happen, where as it is 0.5% in 3-AP-Chn-Mob model when the number of free channels available is just one in the target AP.

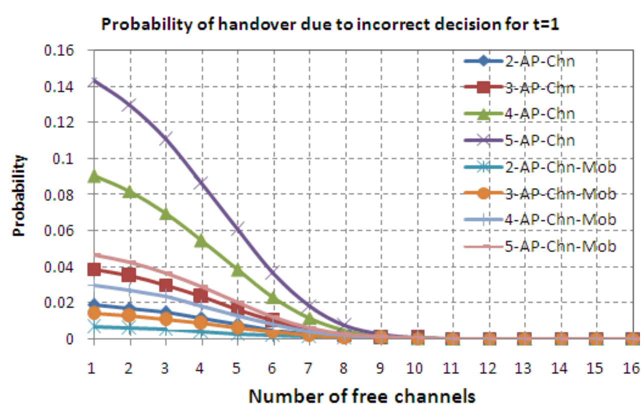

Figure 8 : Total probability of the unsuccessful handoverfor cases with only free channel and free channel plus mobility considered as criteria

Fig. 8 shows the total probability of the unsuccessful handover that has happened for case 1 with only free channel; and free channel plus mobility care considered as criteria, when the mobile node was moving normal to the boundary of the service zone and for the case 1 scenario. The highest probability occurs at 1 free channel with 5-AP-Chn model with 4.5% probability for 5-AP-Chn-Mob model and lowest of 0.9% for 2-AP-Chn-Mob model.

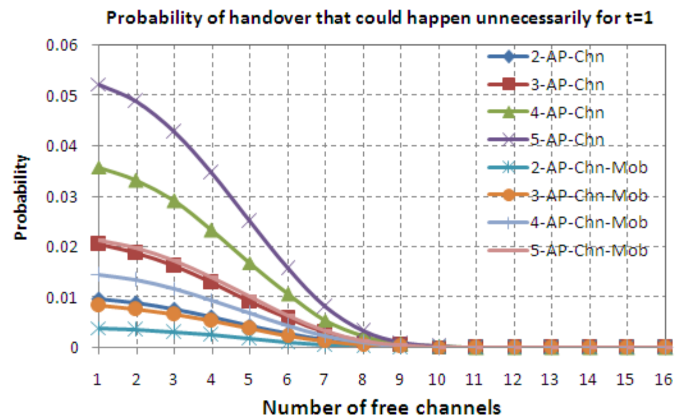

Figure 9 : Probability of the handover that has happened unnecessarily for cases with only free channel and free channel plus mobility considered as criteria

Fig. 9 shows that when there is 1 free channel, the unsuccessful handover probability is 5.2% for the 5-AP-Chn model, and it is 2.1% for 5-AP-Chn-Mob model. The probabilities are reduced again by around 50% when the mobility models are considered. 4-AP-Chn model yielded 3.5% of unsuccessful handover probability that has happened unnecessarily, where as it is 1.5% in 4-AP-Chn-Mob model when the number of free channels available is just one in the target AP. It can be observed that the probabilities have not changed much between the cases of the mobile device moving normal to the boundary to the case of mobile device moving along the boundary, when handover that has happened unnecessarily are considered.

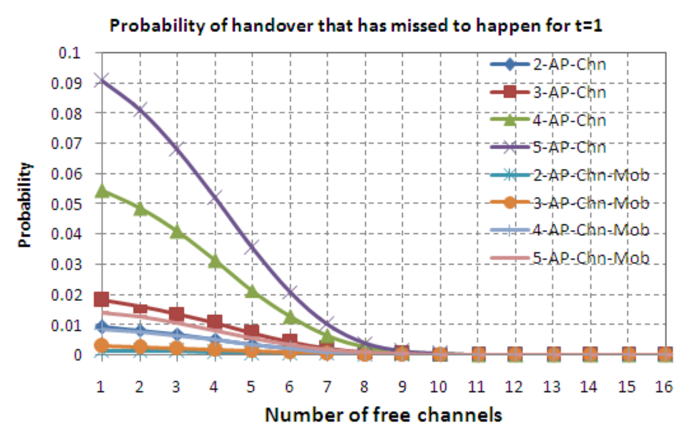

Figure 10 : Probability of the handover that has missed to happen for cases with only free channel and free channel plus mobility considered as criteria

Fig. 9 shows the probability of the handover that has missed to happen. It is clear from Fig.9 that when there is 1 free channel, the unsuccessful handover probability is 1% for the 2-AP-Chn model, and it is 0.2% for 2-AP-Chn-Mob model. The probabilities are reduced by around80% when the mobility models are considered. 3-AP-Chn model yielded 1.9% of unsuccessful handover probability that has missed to happen, where as it is 0.4% in 3-AP-Chn-Mob model when the number of free channels available is just one in the target AP.It can be observed again that the probabilities have not changed much between the cases of the mobile device moving normal to the boundary to the case of mobile device moving along the boundary, when handover that has happened unnecessarily are considered also.

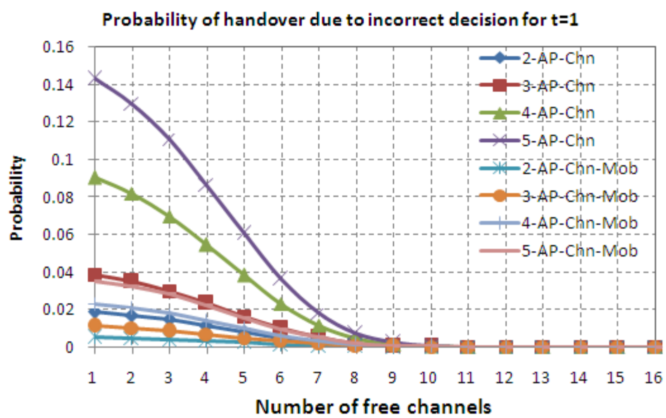

Figure 11: Total probability of the unsuccessful handoverfor cases with only free channel and free channel plus mobility considered as criteria

Fig. 11 shows the total probability of the unsuccessful handover that has happened for case 3 with only free channel; and free channel plus mobility care considered as criteria, when the mobile node was moving along the boundary of the service zone and for the case 3 scenario. The highest probability occurs at 1 free channel with 5-AP-Chn model with 3.5% probability for 5-AP-Chn-Mob model and a lowest of 0.5% for 2-AP-Mob model. It can be observed again that the there is not much improvement in probabilities between the cases of the mobile device moving normal to the boundary to the case of mobile device moving along the boundary, when handover that has happened unnecessarily are considered also. The reason behind this behavior may be attributed to the fact that the historical probability distributions between 8 different turns in Case 1 and Case 2 are almost similar, which is evident from Table 1. However when these distributions are different from each other, a huge difference in the results can be observed.

V. Conclusion

In this work, the handover probabilities for the cases of handover that happened unnecessarily, that has missed to happen and total unsuccessful handover are modeled for the cases of the mobile device moving normal to the boundary and along the boundary of the service zone of AP . Three cases of mobile nodes moving in different set of paths are analyzed and a common procedure is developed to derive the method of computing the handover probabilities. 2-AP, 3-AP, 4-AP and 5-AP models are run by considering only the free bandwidth and free bandwidth plus mobility. The historical data of the probabilities for the movement of mobile devices in pre-identified paths are very important to compute the probability of the mobile device of interest when moving near the boundary. It has been demonstrated that there was more than 50% of improvement in the results when mobility is also considered into the model. Also two cases of historical probability distributions are simulated, and both have yielded similar results since the distribution pattern of historical data is almost same. Probability of the handover that has happened unnecessarily for case 1 and case 3 are 0.4457 and 0.4042 respectively, when only mobility is considered, where as it is 0.2538 and 0.1554 for the probability of the handover that has missed to happen. Since the probabilities between case 1 and case 3 are close to each other for mobility alone, the total probabilities when considered along with free bandwidth is also close to each other.

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