Generalized Probability Model in a WPAN to Compute Handover Probabilities

Ch. Subrahmanyam
Research Scholar Dept. of ECE
Jawaharlal Nehru
Technological University,
Hyderabad.

K. Chennakesavareddy
Ret. Professor from ECE Dept.,
Jawaharlal Nehru
Technological University,
Hyderabad

ABSTRACT
In this work unsuccessful probabilities have been computed for WPAN environment. A new WPAN model has been proposed to reduce the unsuccessful handovers. The models of 2-AP, 3-AP, 4-AP and 5-AP are generalized into an n-AP model in computing the unsuccessful probabilities. Results are presented for different locations of the mobile device in a WPAN environment. It is also shown about the kind of model to be chosen depending upon the location of the mobile device in WPAN. The probabilities of unsuccessful handover that could happen unnecessarily, that has missed to happen and total probability of unsuccessful handover due to incorrect decision are plotted for different decision times and the minimum number of free channels required in each model for maximum successful handovers.

General Terms
Handover probabilities, WPAN, WLAN

Keywords
Unsuccessful handovers, WPAN probability modeling, decision time.

1. INTRODUCTION
WPAN is a growing faster and attracting the research communities attention in the development of new algorithms, analysis of the performance of the WPANs, handover methodologies, development of topologies etc. the WPAN technology is defined in IEEE 802.15.4 standard [1]. The WPAN is basically covers a range of around 10m and uses a transfer rate of 250 Kbit/s. The WPAN operates in the band of 2.4GHz band [2]. Per IEEE 802.15.4 standard uses 16 channels in the 2.4GHz band. These channels start at 2412 MHz and 5MHz apart [2]. In hospitals, airports, railway stations, office spaces etc, there is a high flow of mobile devices entering and leaving the WPAN. The WPANs are equipped with multiple access points and the network need to be optimized for several parameters like number of access points, location of access points (APs), and decision time for handovers. The handover of mobile device from one AP to the other depends on factors like available number of free channels at the target AP, signal strength available, power consumption, mobility of mobile device etc.

The handover can be successful or unsuccessful. The successful handover may be defined as the handover in which the mobile device is transferred successfully to the target AP based on certain decision and the decision continues be valid even after the decision time elapsed. For example, if handover is initiated on the basis that there is, for example, 10 free channels available in the target AP. When the transfer has happened, the number of free channels is still at least 10 in the target AP. This is called as successful handover. If the number free channels become less than 10 at the time transfer, then the decision was incorrect and it is called as unsuccessful handover. In other words, the criterion on which the handover has happened is no longer true when the actual handover too place, resulting in unsuccessful handover.The successful and unsuccessful handover probabilities are computed for a 2 node wireless network based on the bandwidth [3]. The basic definition of the successful and unsuccessful handovers, description of the nomenclatures etc, can be found in the ref [3]. Akhila et.al extended the 2 node wireless network model to 3 node network model for bandwidth and received signal strength criteria [4-6]. Suresh et. al used a five node model considering the nodes in wireless network in different states like cooperative state, malicious state, failed state etc [7-11]. In general, handover algorithms based on signal strength have been evaluated for its performance using analytical models in ref. [12]. Similarly, the performance was analyzed based on bandwidth available and access delay in ref. [13].

However, all these models focused on the single AP models like 2 nodes or 3 nodes or 5 nodes alone, there was no common model developed which can handle varying number of nodes in the algorithm. There is no probability model developed for a 4 node model available in the literature. The above models did not focus on the WPAN applications and did not provide the optimization of location of the access points or the minimum number of free channels required for the successful handovers. The above models did not derive the approach to arrive at the parameters to achieve highest successful handover rates. Also the models in [2-8] did not focus on a WPAN kind of applications where one has to chose models having varying number of nodes.In this work, an attempt is made to address the issues of variable number or access points available in a WPAN for the handover to take place. Also, a generalized probability model has been developing to compute the probabilities in a WPAN environment. Also, an approach has been proposed to reduce the unsuccessful handover probability in this work.

In the next section, physical model and handover approach in a WPAN environment has been proposed. In Sec.III, the generalized probability model has been developed. In Sec IV, the simulation results are presented for the 2-AP, 3-AP, 4-AP and 5-AP models using the generalized probability models developed in Sec. III. The results presented are probability of unsuccessful handover that could happen unnecessarily, probability of unsuccessful handover that has missed to happen and total probability of unsuccessful handover due to incorrect decision. Finally, important conclusions are drawn in Conclusions section.

2. PHYSICAL MODEL AND HANDOVER APPROACH

Consider a room fitted with 5 access points (AP) in WPAN or WLAN. APs are located at four corners of the room and at the center point of the room ceiling. These AP are, namely, AP-NE, AP-NW, AP-SW, AP-SE and AP-C. Size of the room is L meters in length and the room considered here is of square type. The AP-C has a range of D/2 meters radial direction. The AP-NE, AP-NW, AP-SW, and AP-SE have the range equal to L/2 meters as shown in Fig.1. It can be observed from the Fig.1 that there is a zone of overlap in the ranges of the AP-C and AP-NE, AP-NW, AP-SW, and AP-SE separately. Fig.1 shows 14 mobile devices that are located at several point in the room. These mobile devices are assigned the APs depending upon their location with respect to the APs. Each mobile device send back a signal after receiving the signal from each of the AP, to all the APs. The mobile device after receiving the signal from the AP, modifies it to an index known as Received Signal Strength Index (RSSI) depending up on the strength the signal it received. When the RSSI is sent back to the APs, the APs can calculate the distance of the mobile device based on the pre-populated data. The mechanism of calculating the distance of the mobile device with APs are beyond the scope this work and has been presented here in brief terms for the understanding of reader.

When the mobile devices are in location M1, it is in the zone of AP-NW that is in the arc of A-B with AP-NW as the center of the arc and hence it will be connected to the AP-NW. AP-NW provides services to the mobile devices that there inside this arc. However, it can establish the connections with the devices outside this arc temporarily. This is important to reduce the power consumption by the APs. Similarly, M2, M3 and M4 are connected to AP-NE, AP-SE and AP-SW respectively. This case is treated as 1-AP handover model in this work.When the mobile devices are in the location M5, it is in the overlap zone of two APs, namely, AP-C and AP-NW. Since the overlapping zone is close to AP-C than that of AP-NW, the mobile device at location M5 is first connected to AP-C. Similar approach is adopted for the mobile devices located at M6, M7 and M8. The AP-C has certain bandwidth or the maximum number of channels it can support. When there are more number of mobile devices joining in the green zone shown in Fig.1, which is very close to that of the overlapping zone of AP-C and AP-NW, the AP-C wants handover the mobile device to the AP-NW since AP-NW is the next closest AP. That when AP-C gets a request from the mobile device, AP-C gets distance of location of mobile device. For example M13 is making request t AP-C. Since M13 is closer than M5 which is already connected to AP-C, the AP-C decides to handover the M5 to AP-NW. Hence the designations M5 and M13 are interchangeably used to specify the location as well as the mobile device located at the point. In case if the M5 cannot be transferred to the AP-NW then AP-C retains the M5 with it. As the AP-C keeps on accepting the new mobile devices, then the number of occupied channels will keep on increasing and at each of the new request, AP-C keeps on trying to transfer the already connected mobile devices to the AP-NW to free up its bandwidth. In case the bandwidth is full and the new request keeps on coming, the AP-C will reject the request and the mobile device tries with the other nearest APs for establishing the connection. In this scenario, the probability of the handover is computed in this work by conspiring it as a two node case. The similar procedure is adopted by AP-C with other APs, namely, AP-NE, AP-SE and AP-SW and those cases are considered as 2-AP models. That means if the mobile devices are in the overlapping zone, then it is treated as 2-AP handover model for calculating the handover probabilities. When the mobile device (M9) is in the zone of A-C-D, it is not in the service zone of any of the three nearest APs, namely, AP-NW, AP-SW and AP-C. Mobile device sends an RSSI and establishes a connection with the AP-NW, AP-SW or AP-C depending up the nearest distance criteria and bandwidth availability with that AP. Assume that it established a connection with AP-NW temporarily. When AP-NW receives more requests from its service zone, the AP-NW decides to handover M9 to AP-SW or AP-C. In case the handover does not happen, then AP-NW retains M9 with itself for some more time. In this case it is treated as a three node network. That means whenever the mobile device is in the zone of A-C-D, then handover probabilities are computed by treating the network as a 3-AP handover model.

When there are more requests coming from the service zone of AP-C that is marked in white circle in Fig.1, it decides to off load other farther mobile devices located in the green zone in Fig.1, which is also in the service zone of AP-C, to other neighboring APs. Assume that AP-C has all the mobile devices located in the white circle zone to its full bandwidth, then any new request coming from the green zone will be directly handed over to the neighboring APs. In such a case, it is treated as 4-AP handover model. In case the new request comes from the zone within the white circle, then it is treated as a 5-AP handover model.

3. PROBABILITY MODEL

Consider five APs having the maximum number of available channels as A1, A2, A3, A4 and A5. The capacity of each AP is to be decided depending upon their location in the room and the traffic it is expected to handle at that location. The models that are considered in this work for computing the handover probabilities are

- 1-AP handover model
- 2-AP handover model
- 3-AP handover model
- 4-AP handover model and
- 5-AP handover model

There is no handover that is required in case there is only one AP that is serving a zone. Hence the probability of successful handover is 1 or 0.

Table 1. Handover models for several location of the mobile device

Mobile Device Location	Bandwidth in the nearest AP	Number of APs in the Model
M0	Available	1
M1	Available	1
M2	Available	1
M3	Available	1
M4	Available	1
M5	Available and Full	2
M6	Available and Full	2

M7	Available and Full	2
M8	Available and Full	2
M9	Available and Full	3
M10	Available and Full	3
M11	Available and Full	3
M12	Available and Full	3
M13	Available	1
M13	Full or Near Full	4
M0	Full	5

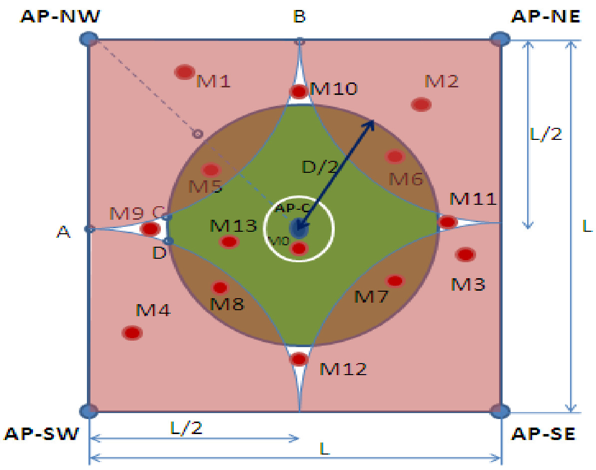

Fig 1: Location of the mobile devices and the Access points for WPAN/WLAN in a room

For the case of handover in a 2-AP handover model, the mobile device needed to be handed over from one AP to another depending upon certain conditions. These conditions can be like number of free channels available in the target AP compared to the host AP, signal strength offered by the target AP compared to the host AP, power consumption, direction of the movement of the mobile device, location of the mobile device with respect to the target AP etc.For the cases of 3-AP, 4-AP and 5-AP handover models, there more APs available for the host AP to transfer the mobile device to. Again if the host AP decides to transfer the mobile device to a target AP, then the target AP is chosen based on the number of free channels available, for a example. That is the target AP is the one that has highest number of free channels compared to the other APs available in the model. In a 5-AP model, there are five APs, namely, AP1, AP2, AP3, AP4 and AP5. Assume that the host is AP1 and wants to transfer the mobile device to AP2, AP3, AP4 or AP5. If AP3 has maximum number of free channels available compared to AP2, AP4 or AP5, then the mobile device is transferred to AP3. Or, one can decide the handover initiation based on other parameters like signal strength offered by the target AP compared to the host AP, power consumption, direction of the movement of the mobile device, location of the mobile device with respect to the target AP etc.

In this work a generalized model is developed for computing the successful handover probability, unsuccessful handover probability due to wrong decisions made. The decisions can go wrong in cases like, if the host AP wants to transfer the mobile device since the number of free channels available in the target AP is higher than that in the host AP. To verify that, the host AP probes and takes the decision based on the comparison. However, by the time the transfer actually happens, the conditions at the target AP might have changed. That is after a time *t* the number of free channels available in the target AP becomes lower than that in the host AP. In this case, the mobile device was transferred unnecessarily. In the other case, when the number of free channels available in the host AP is higher than that in the target AP, the host AP decides to keep the mobile device with it. But in the time *t*, the number of free channels available in the target AP may become higher than that in the host AP. In this case, the handover had not happened though it should have actually happened. That means the host has missed to handover the mobile device to target AP. The scenarios become more complex as the number of APs increase in the model. That is the 5-AP model is more complex than that of 2-AP for handover decision making.

Let A1, A2, A3, ….,An are the maximum number of available channels in access points AP1, AP2, AP3,….APn. Consider a Markov model that has n-states.

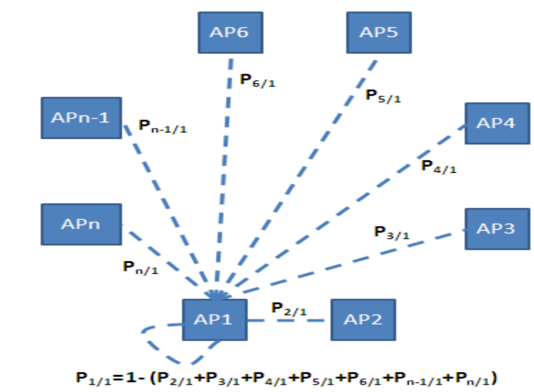

Fig 2: WPAN having n Access Points where the mobile device is presently in AP1 and wants to find a target AP for handover

Fig. 2 shows the WPAN having n Access Points where the mobile device is presently in AP1 and wants to find a target AP for handover. $P_{2/1}$ is the probability of the mobile device moving from AP1 to AP2, $P_{3/1}$ is the probability of the mobile device moving from AP1 to AP3 and so on. $P_{1/1}$ is the probability of the mobile device continues to stay in AP1 after time *t*.

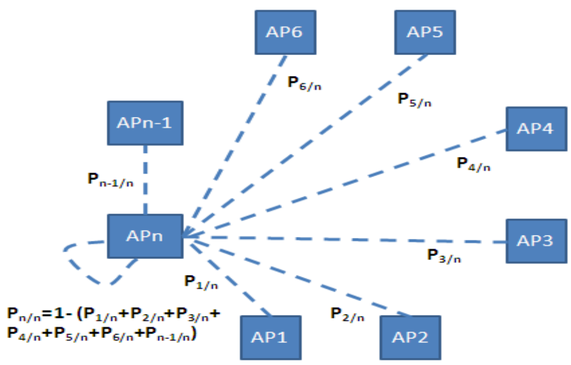

Fig 3: WPAN having n Access Points where the mobile device is presently in APn and wants to find a target AP for handover

Fig.3 shows a generalized model where the mobile device is presently in the APn and wants to be handed over to the other APs. The all other APs are denoted as AP1, AP2,….,,APn-1.

The probability that mobile device continues to stay in APn is given by

$$P_{n/n} = 1 - \left(P_{1/n} + P_{2/n} + P_{3/n} + P_{4/n} + \ldots\ldots + P_{n-1/n}\right) \quad (1)$$

Probability that the mobile device present in the APn is given by

$$P_n = \frac{P_{n/1} + P_{n/2} + \ldots. + P_{n/n-1}}{P_{1/n} + P_{n/1} + P_{2/n} + P_{n/2} + \ldots\ldots + P_{n-1/n} + P_{n/n-1}} \quad (2)$$

$$P_n = \frac{\sum_{i=1}^{n-1} P_{n/i}}{\sum_{i=1}^{n-1} P_{n/i} + P_{i/n}}$$

(3)

The probability of mobile device moving from AP1 to AP2 is equal to the probability of (A2-A1 >X), where X is the threshold limit. That means if the A2 is greater than A1 by L number of free channel, the decision for handover happens.

$$P_{n-1/n} = P\{A_{n-1} - A_n \geq X\} \quad (4)$$

Handover probabilities for such an arrangement are given by

$$P_h = \frac{1}{n}\left\{\sum_{i=1}^{n} P_i \left[\sum_{\substack{j=1 \\ j\neq i}}^{n} P_{j/i}\right]\right\} \quad (5)$$

Let, the probability of occupied number of channels is given by

$$\prod_{n,k} = \frac{\rho_i^k}{k! \sum_{j=0}^{A_i} \frac{\rho_n^j}{j!}}$$

(6)

where ρ_i is the traffic load in access point *i.*

For an M/M/B process, the arrival rate of requests channels follows a Poisson's distribution with parameter λ_i and service rate is given by

$$\Psi_i = \lambda_i (A_i - k) / A_i$$

(7)

$$P_{hu} = \sum_{i=1}^{n} \sum_{\substack{j=1 \\ j\neq i}}^{n} P_i P_{j/i} \sum_{m=X}^{A_j} \prod_{j,A_j-m} \sum_{k=0}^{m-X} \prod_{i,A_i-k} \Omega_i(k,r,t) \bullet \sum_{n=0}^{A_i} \prod_{i,A_i-n} \sum_{k=n+X}^{A_j} \prod_{j,A_j-k} \Phi_j(k,r,t)$$

(8)

Where P_{hu} is the probability of handover happened unnecessarily as the conditions might have changed adversely in the target AP.

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

(9)

Where P_{hm} is the probability that handover has missed to happen as the conditions might have changed favorably in the target AP.

where

$$\Omega_i(k,r,t) = \sum_{p=0}^{A_i-k} \frac{(\Psi_i t)^p}{p!} e^{-\Psi_i t} \bullet \sum_{q=0}^{p+k-r} \frac{(\lambda_i t)^q}{q!} e^{-\lambda_i t}$$

(10)

and

$$\Phi_i(k,r,t) = \sum_{p=0}^{A_i-k} \frac{(\Psi_i t)^p}{p!} e^{-\Psi_i t} \bullet \left[1 - \sum_{q=0}^{p+k-r} \frac{(\lambda_i t)^q}{q!} e^{-\lambda_i t}\right].$$

(11)

The unsuccessful handover probability due to incorrect decision is given by

$$P_{ush} = P_{hu} + P_{hm}$$

(12)

4. SIMULATION RESULTS

The probability of hand over is plotted in Fig. 4 for the number of free channels ranging from 1 to 16. The number free channels are same when the probability is computed in all the models of access points considered. That means in case of a 2-AP problem, the plot shows the probability of handover when there are same numbers of free channels. When 15 channels are occupied and only 1 channel is free, the probability if handover is 0.56. The probability of handover falls thereafter up to 7. This is because of the reason that as the number of free channels increase, there is more probability of change in both the access points and hence even if one AP has moved to one free channel from two free channels, then the handover does not happen.

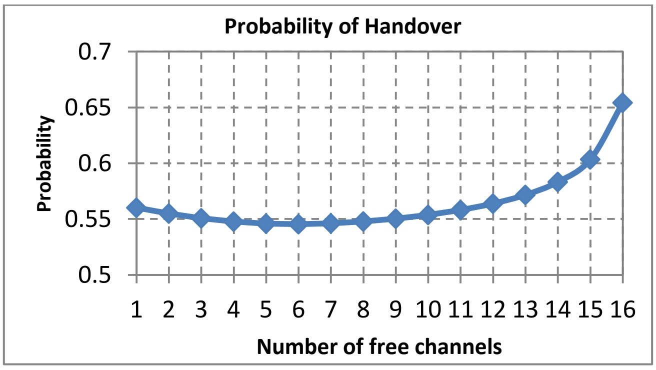

Fig 4: Probability of handover

When the number of free channels increase to half the number of maximum number of free channels, that is 8 in this case, the probability increases as even if handover takes place, there are free more channels available to accept the mobile device and hence handover is successful. The maximum probability of handover occurs when all the channels are free. The handover probability decreases up 50% of the maximum number of free channels in the model and it increases thereafter. This behavior is observed when the maximum number of free channels is changed from 16 to 20 or 50.

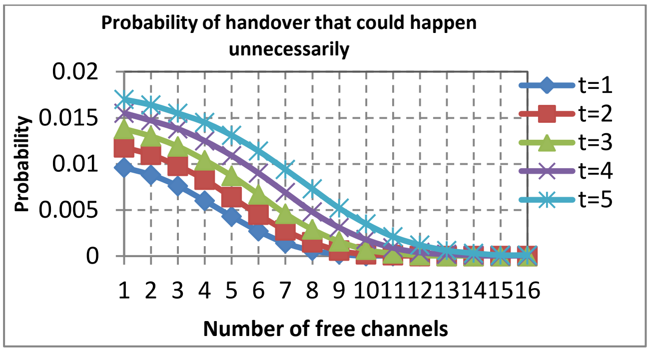

Fig 5: Probability of unsuccessful handover that could happen unnecessarily in 2-AP WPAN

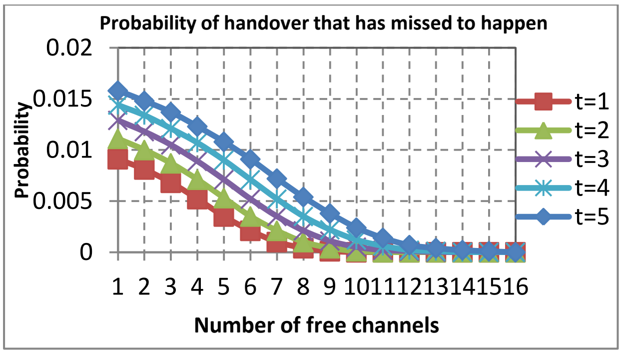

Fig 6: Probability of unsuccessful handover that has missed to happen in 2-AP WPAN

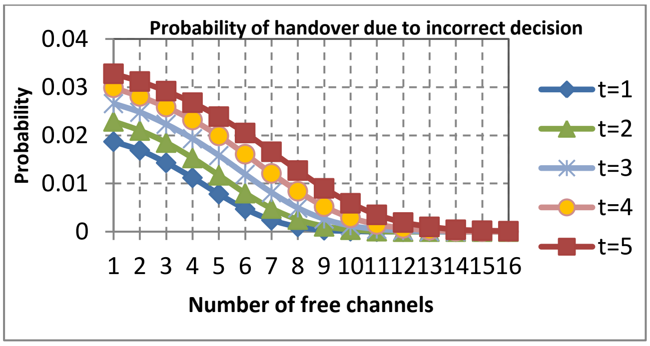

Fig 7: Total Probability of unsuccessful handover due to incorrect decision in 2-AP WPAN

Figs. 5, 6 and 7 show the probability of unsuccessful handover that could happen unnecessarily, probability of unsuccessful handover that has missed to happen and total probability of unsuccessful handover due to incorrect decision respectively, for 2-AP WPAN model for decision times 1ms, 2ms, 3ms, 4ms and 5ms. The probability of unsuccessful handover due to incorrect decision is equal to the sum of probability of unsuccessful handover that could happen unnecessarily and that has missed to happen. In all the three plots, it can be observed that, the unsuccessful handover probabilities increase with increase in the decision time. This is due to the reason that as the decision time is more, there is more probability that the conditions at the target AP changes. Since the handover happens based on the available number of free channels on the target AP, the decision time is the key factor in the probability of unsuccessful handover. Larger the decision time, higher the probability that the number of free channels change at the target AP. It can also be observed that as the decision time increases from t=1ms to 5ms, the number free channels required for the getting the probabilities to zero also increases. That is, in case of probability of unsuccessful handover that could happen unnecessarily, the probability gets close to zero when the number of free channels are above 9 for t=1ms and it becomes close to zero when the number of free channels are above 12 for t=3ms. The unsuccessful probability never gets close zero for t=5ms. That means for a 2-AP model, the decision time cannot be chosen above 4ms.

Fig. 8 shows the probabilities of unsuccessful handover in 2-AP WPAN for the case of t=1. It shows the relative contribution of the probability of unsuccessful handover that could happen unnecessarily and probability of unsuccessful handover that has missed to happen to the total probability of unsuccessful handover due to incorrect decision. For 2-AP model, the contribution to the total probability is almost close to each other. All the probabilities for t=1ms, gets close to zero after number free channels are above 9.

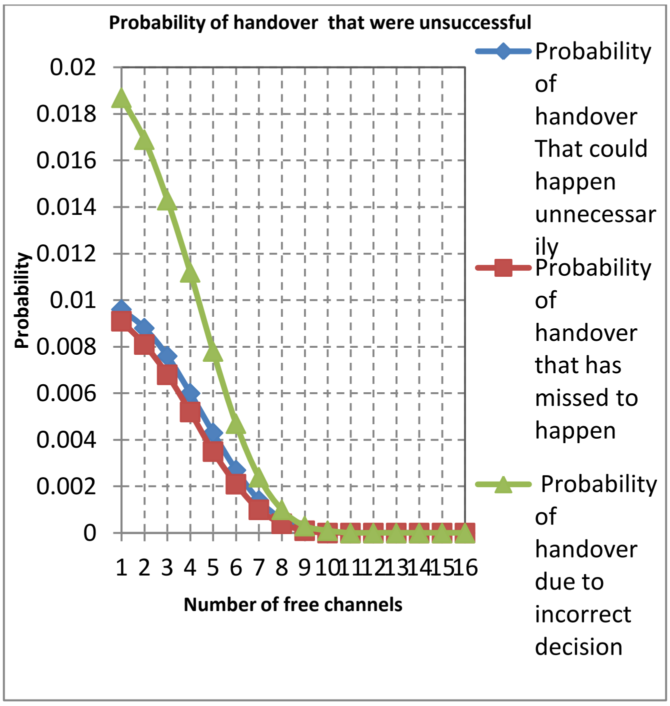

Fig 8: Probabilities of unsuccessful handover in 2-AP WPAN for t=1

That means, when the t=1ms and when the mobile devices in the locations M5, M6, M7 and M8; the number of free channels must be equal to a minimum of 10 to avoid any unsuccessful handovers when the maximum number of free channels are 16. This is not practical as it is not possible to have 10 out the 16 channels always free. The other way to reduce the unsuccessful handover is to reduce the decision time as low as possible. This is demonstrated in the above plot when the decision time is reducing from 5ms to 1ms. I order to take the decisions faster; one should employ the high end hardware in the WPAN.

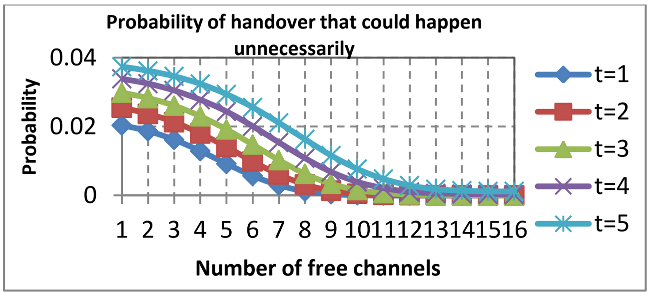

Fig 9: Probability of unsuccessful handover that could happen unnecessarily in 3-AP WPAN

Figs. 9, 10 and 11 shows the probability of unsuccessful handover that could happen unnecessarily, probability of unsuccessful handover that has missed to happen and total probability of unsuccessful handover due to incorrect decision respectively, for 3-AP WPAN model for decision times 1ms, 2ms, 3ms, 4ms and 5ms.It can be observed in the 3-AP model, the unsuccessful probability never gets close zero for t=4ms and 5ms. That means for a 3-AP model, the decision time cannot be chosen above 3ms.

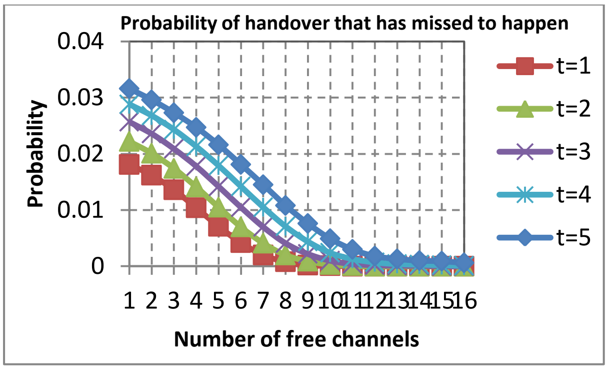

Fig 10: Probability of unsuccessful handover that has missed to happen in 3-AP WPAN

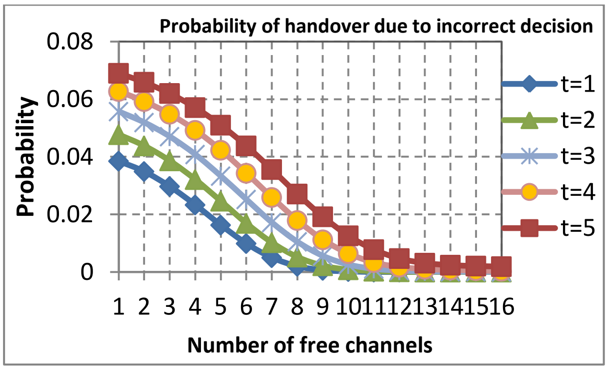

Fig 11: Total Probability of unsuccessful handover due to incorrect decision in 3-AP WPAN

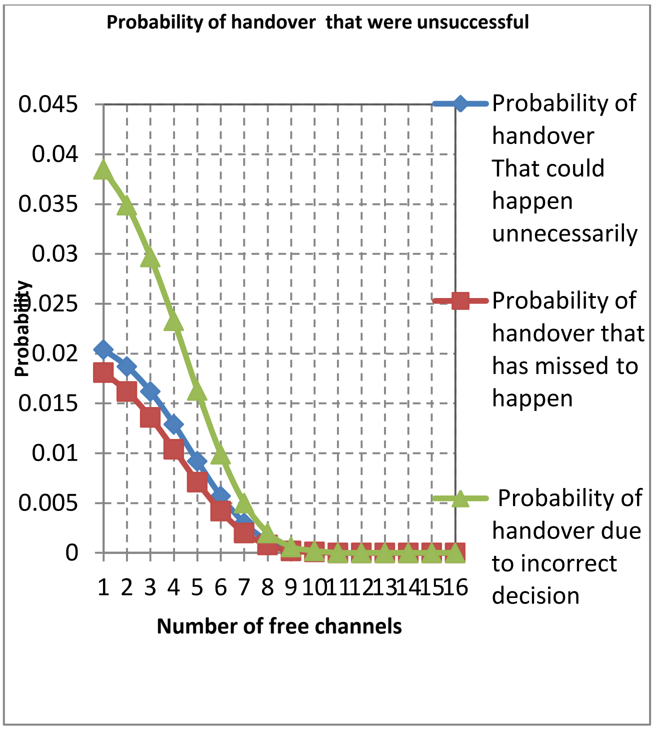

Fig 12: Probabilities of unsuccessful handover due to in 3-AP WPAN for t=1

Fig. 12 shows the probabilities of unsuccessful handover in 3-AP WPAN for the case of t=1. It shows contribution of the probability of unsuccessful handover that could happen unnecessarily is slightly higher than the probability of unsuccessful handover that has missed to happen. All the probabilities for t=1ms, gets close to zero after number free channels are above 10. That means, when the t=1ms and when the mobile device is located at M9, M10, M11 and M12; the number of free channels must be equal to a minimum of 11 to avoid any unsuccessful handovers when the maximum number of free channels are 16.

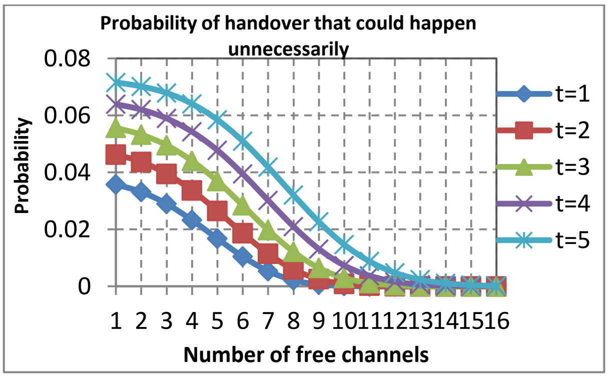

Fig 13: Probability of unsuccessful handover that could happen unnecessarily in 4-AP WPAN

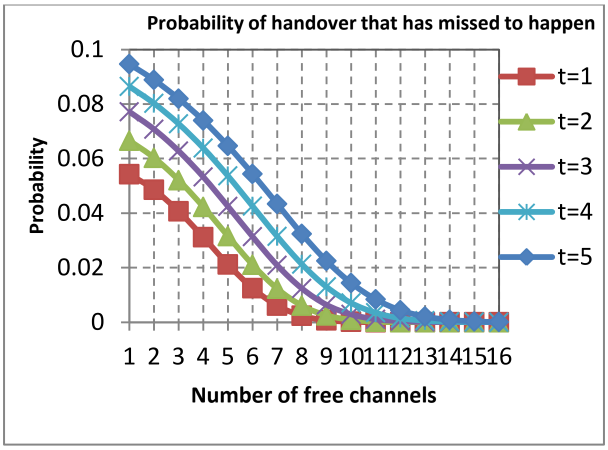

Fig 14: Probability of unsuccessful handover that has missed to happen in 4-AP WPAN

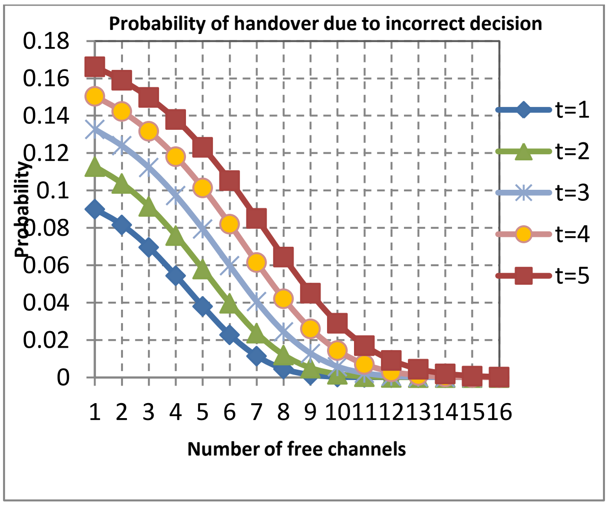

Fig 15: Total Probability of unsuccessful handover due to incorrect decision in 4-AP WPAN

Figs. 13, 14 and 15 show the probability of unsuccessful handover that could happen unnecessarily, probability of unsuccessful handover that has missed to happen and total probability of unsuccessful handover due to incorrect decision respectively, for 4-AP WPAN model for decision times 1ms, 2ms, 3ms, 4ms and 5ms. It can be observed in the 4-AP model, the unsuccessful probability never gets close zero for t=5ms. That means for a 4-AP model, the decision time cannot be chose above 4ms.

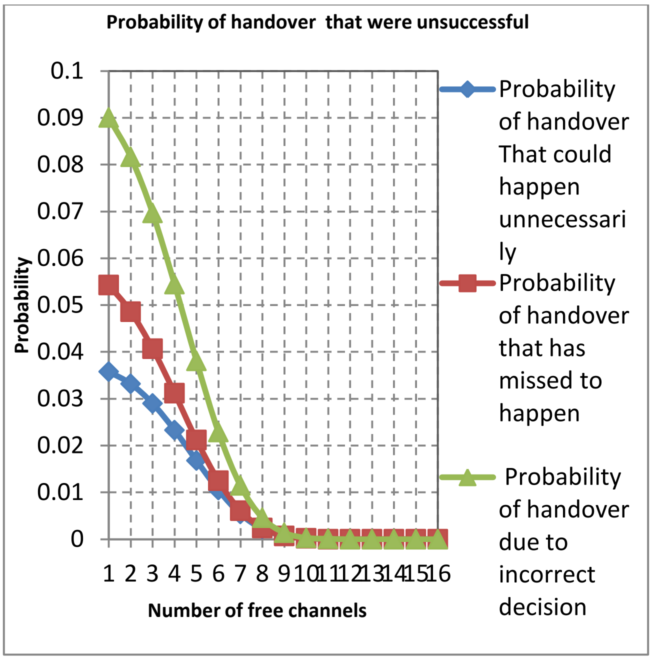

Fig 16: Probabilities of unsuccessful handover due to in 4-AP WPAN for t=1

Fig. 16 shows the probabilities of unsuccessful handover in 4-AP WPAN for the case of t=1. It shows contribution of the probability of unsuccessful handover that could happen unnecessarily is lower than the probability of unsuccessful handover that has missed to happen. All the probabilities for t=1ms, gets close to zero after number free channels are above 10. That means, when t=1ms and when mobile device is located at M13 with all the free channels occupied in the AP-C, the number of free channels in the other APs must be equal to a minimum of 11 to avoid any unsuccessful handovers when the maximum number of free channels are 16.

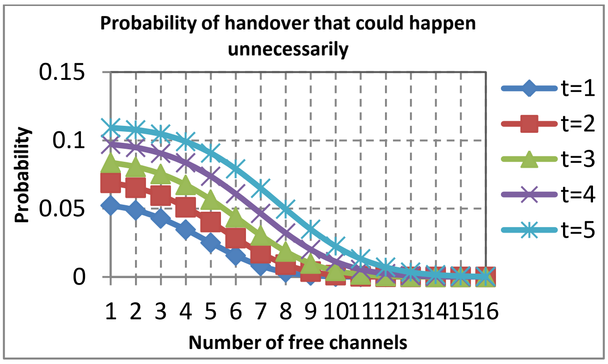

Fig 17: Probability of unsuccessful handover that could happen unnecessarily in 5-AP WPAN

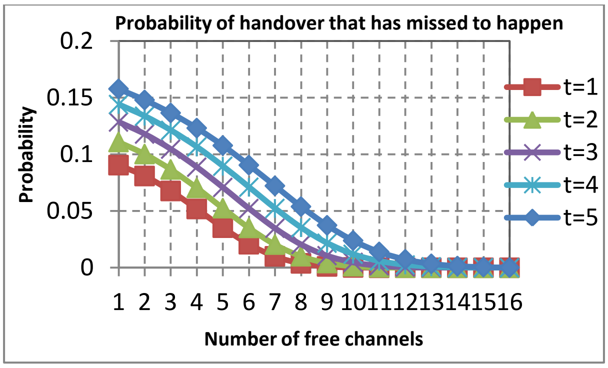

Fig 18: Probability of unsuccessful handover that has missed to happen in 5-AP WPAN

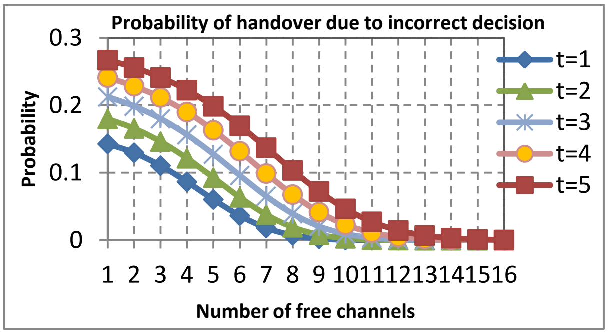

Fig 19: Total Probability of unsuccessful handover due to incorrect decision in 5-AP WPAN

Figs. 17, 18 and 19 show the probability of unsuccessful handover that could happen unnecessarily, probability of unsuccessful handover that has missed to happen and total probability of unsuccessful handover due to incorrect decision respectively, for 5-AP WPAN model for decision times 1ms, 2ms, 3ms, 4ms and 5ms. It can be observed in the 5-AP model, the unsuccessful probability never gets close zero for t=5ms. That means for a 5-AP model, the decision time cannot be chose above 4ms.

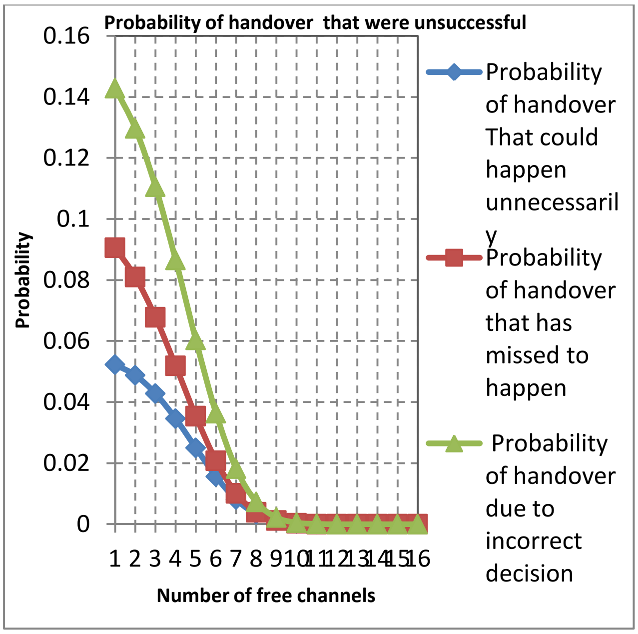

Fig 20: Probabilities of unsuccessful handover due to in 5-AP WPAN for t=1

Fig. 20 shows the probabilities of unsuccessful handover in 5-AP WPAN for the case of t=1. It shows contribution of the probability of unsuccessful handover that could happen unnecessarily is much lower than the probability of unsuccessful handover that has missed to happen. All the probabilities for t=1ms, gets close to zero after number free channels are above 10. That means, when the t=1ms and when the mobile device is at location M0 and when AP-C is full, the number of free channels must be equal to a minimum of 11 to avoid any unsuccessful handovers when the maximum number of free channels are 16.

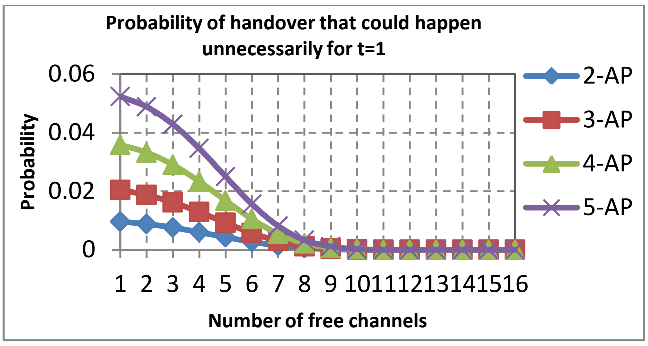

Fig 21: Probability of unsuccessful handover that could happen unnecessarily for t=1 in different models

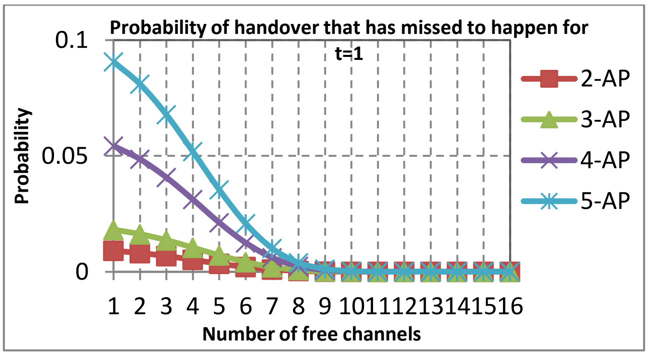

Fig 22: Probability of unsuccessful handover that has missed to happen for t=1 in different models

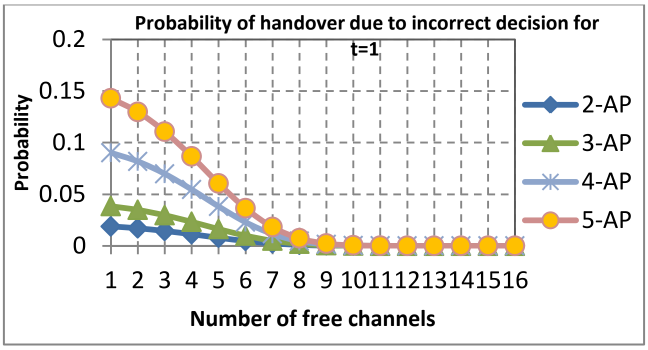

Fig 23: Total Probability of unsuccessful handover due to incorrect decision for t=1 in different models

Figs. 21, 22 and 23 show the probability of unsuccessful handover that could happen unnecessarily, probability of unsuccessful handover that has missed to happen and total probability of unsuccessful handover due to incorrect decision respectively, for 2-AP, 3-AP, 4-AP and 5-AP WPAN model for decision times 1ms. The results are repeated here just to the comparison of the probabilities when the access point models change. For the same decision time, the 2-AP model yield lowest unsuccessful handovers compared to all the other three models. The 5-AP yield the highest unsuccessful handovers. This is due to the reason that, higher the number of available access points for the handover, higher the probability that conditions will change when the actual handover takes place. However, the differences become negligible when the numbers of free channels available are above 10 in all the access points. This is not feasible since it is not possible to maintain all the access points with more than 50% bandwidth is free. Hence one should focus on reducing the decision time to reduce the unsuccessful handovers.The unsuccessful probabilities can be reduced either by choosing the smaller decision times or forcing the mobile node at locations where the 2-AP models are applicable. Also the unsuccessful probabilities can be reduced close to zero when the number are free channels available are always above 10 as shown in Fig. 22.

5. CONCLUSIONS

In this work probabilities of unsuccessful handover that could happen unnecessarily, that has missed to happen and total probability of unsuccessful handover due to incorrect decision respectively, are computed for 2-AP, 3-AP, 4-AP and 5-AP WPAN model for decision times 1ms to 5 ms. It has been observed that the higher the decision time higher the probability of unsuccessful handovers. Similarly, higher the number of access points chosen for handover, higher will be unsuccessful probability. That means when the mobile device is at locations of M5, M6, M7 and M8, the probability of unsuccessful handovers are minimal and when then mobile device is at the locations of M0 and M13 with the AP-C being full, then the unsuccessful hand over is very high. When one channel is free in all the access points, the handover is unsuccessful with 14% probability when the mobile device is at M0 and AP-C full, than the case of mobile device being present at M5 which yields only 2% of unsuccessful handovers. Hence, when the handover is planned, the number of access points to be chosen only two. But this depends on the decision time availability if both the access points are full. Or, it should be planned to locate the access points in such way that area where majority of mobile devices present should be covered by M5 kind of locations to reduce the unsuccessful handovers in a WPAN.

6. REFERENCES

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