Static channel versus dynamic channel allocation systems computer science

Abstract- Channel Allocation Schemes have always held a vital role in achieving better performance of wireless networks. This paper has studied the comparison between two of the most known techniques of channel allocation namely: Static Channel Allocation and Dynamic Channel Allocation. The comparison is made over two types of networks single radio network, in which each of wireless node is equipped with only one radio interface, and multi radio network, in which each of the node is equipped with at least two transceivers. This paper presents the detail survey of all the existing comparison made between these two schemes.

Keywords- Channel Allocation Scheme, Dynamic Channel Allocation, Static Channel Allocation, Single radio network, Multi-radio network

Introduction

Growth in the customers of the wireless networks, let it be cellular systems or any other Wireless network, has amplified the need to have the networks which can have more capacity and accommodate more and more users. Enlargement of wireless market has made capacity of the wireless network a scarce resource. Methods to improve effective capacity utilization of the wireless network are under consideration and in [4], it is realized that these methods involve source coding schemes, power control, better modulation schemes, improved antennas. Other then these methods capacity of wireless system can be improved by installing more bas stations i. e increasing number of transmitting equipment or improving hardware equipment of current system. Using better channel allocation schemes is also one of the methods to improve capacity utilization of wireless network.

The aim of this paper is to focus on channel allocation schemes. These channel allocation schemes are not much of importance in the wired networks because their topology is stable and they do not offer any mobility to the users/nodes. But in the wireless networks, channel allocation of key importance. The vital role of the wireless networks is that they offer mobility to users hence, the channel allocation algorithm has to assign channels to ports and portables so that best trade-off between the quality of service and system performance is maintained [3].

A given spectrum of frequency, can be divided into several independent sets, these independent sets are completely disjoint with each other. Hence even if they are used simultaneously, they will not interfere with each other. So splitting the frequency spectrum into independent channels and then using all the channels for communication simultaneously present improvement in the capacity utilization [6].

The channel allocation strategy is considered to be the core of mobile networks because it not only affects the quality and the availability of the channels to the user but changes the distribution of the traffic and hence, overall shapes the capacity of the network [3].

Two of the most common channel allocation schemes are considered in this paper namely, FCA- Fixed Channel Assignment or Fixed Channel Allocation and DCA- Dynamic Channel Allocation.

Fixed Channel Allocation (FCA)

Fixed Channel Allocation is also known as Static Channel Allocation. It is known as Fixed or Static because once the channel is allocated to a port or a user it does not change for the entire course of operation. It is used in all TDMA/FDMA digital cellular mobile networks [5] as number of frequency carriers in each cell stays fixed and does not depend on traffic load. It is a time insensitive solution, as with the passage of time allocation of the channels to nodes does not change. Although in real-time, traffic load in a cell varies, there are peak hours when the traffic load reaches to almost 100% and then there are quiet hours in a cell when traffic load is very low. This limitation dispirits the use of the FCA. But if a static condition is considered there is most likely a chance to get good performance with this channel allocation algorithm [3].

In a cellular system based on the FCA, channels are partitioned among the cells permanently so that if all the cells use all the channels assigned to them simultaneously, there will be no interference [1].

Figure – cell pattern for Static Channel Allocation with N = 7

With more complex systems other channel strategies can achieve higher efficiency but they require processors with more memory. But it is an essential sacrifice to make as in [4] it is discussed that in each cell there are no static conditions, space traffic imbalance varies from 10% to 70%, and this imbalance in the traffic depends on the size of the cell or service area and type of the environment, whether its urban, suburban or rural area [4].

Dynamic Channel Allocation (DCA)

In DCA, frequency channels are not fixed for any node or user. Depending upon knowledge of the environment, channels are assigned to the user. The distribution of the frequency carriers in a cell depends upon distribution of the users/nodes in the cell and also on offered traffic load. DCA is currently supported by the GSM [5]. In Dynamic Channel Allocation Scheme all the channels which are available for a system, are kept in a queue or a spool. These channels are allocated to any cell temporarily. The only constraint is to fulfil the distance criteria, so that interference can be minimized [2].

The existing schemes for the Dynamic Channel Allocation can be categorized into three main types: IA-DCA (Interference Adaptive Dynamic Channel Allocation), LA-DCA (Location Adaptive Dynamic Channel Allocation) and TA-DCA (Traffic Adaptive Dynamic Channel Allocation), these schemes are based on the type of network dynamics they consider while making decision [4]. All DCA schemes basically evaluate the cost of using each available channel and opts the channel which introduces lowest cost [2].

For most accurate and good decision for channel allocation, the algorithm should have accurate knowledge of the environment [3]. The main algorithms which are considered under the study of Dynamic Channel Allocation are: DCET, Bellcore and Segregation DCA [3]. In DCET and Bellcore DCA algorithms, the decision of channel allocation is based on only single measurement of channel dynamics, while in the Segregation DCA, a radio interface acquires the channel depending upon its learning through past experience of channel usage. With the past knowledge, channel which has highest probability of success is chosen for operation. Although this algorithm requires processors with memory yet as decision is more

meaningful so its performance is better than the DCET and Bellcore DCA algorithms [3].

In figure 2, in [7] results of performance of different type of DCA schemes are compared.

Figure – Performance of Different DCA methods

Section II of the paper compares both of the channel allocation schemes in a single radio network and Section III shares the comparison done of channel allocation schemes in multi-radio network. Section IV shares the identified regions in which future work can be done and Section V concludes the paper.

Comparison of DCA and FCA in Single Radio Network

A single radio network a network in which all of the nodes of the wireless network consist of maximum of one radio interface and this single radio interface is used for the communication purposes. In this section the comparison of the DCA and FCA in single radio network is presented.

Figure – Algorithms for Dynamic Channel Allocation

In a given cell, if a node requests a call, it will be served only and only if the cell has an unused channel available, which fulfils the reuse criteria, otherwise the call will be blocked [1]. Such is the case with Static Channel Allocation Scheme. But this is not the case with the Dynamic Channel Allocation Schemes, as for each of the call that is to be served; channel is taken from the overall pool that holds all the channels available for wireless system.

In any channel allocation strategy, main aim is to find the best possible way to reuse the channels to maximize the systems' capacity, while keeping interference in the system at minimum and provide quality of service to the user [4]. From another view, for allocating channel, the objective is taken as to allocate the channel to a call so that number of blocked calls is minimized and the number of dropped calls is also minimized. In the end, the channel allocation scheme finds the best trade-off between these two objectives because generally priority is given to minimize the number of dropped calls, as having a call dropped is more undesirable then not having the call connected at all [1].

Both schemes for channel allocation FCA and DCA are compared under the assumption that the call arrival distribution is Poisson [5]. For the purpose of modelling in FCA it is considered that there are z numbers of channels per frequency carrier and y is the number of control channels. In a given cell i, let total number of frequency carrier be Ci and the total number of channels in the cell, which will be used to serve a call will be ci. The expression for ci is given as:

(1)

While this will not be the case for DCA, as frequency carriers are not permanently assigned to any of the cell. As the channel assignment depends on environment so, if we take n as the number of active calls in any cell, then frequency carriers allocated to that cell will be:

(2)

Total number of channels required, for any cell should be equal to the number of active calls and the control channels. But the number of frequency carriers which has z number of channels each should be either more or equal than actually required [5].

In equation (2), shows that value is always taken equal or greater than " a" [5].

For the first simulation, the arrival rate of the calls is set at the overload value; this means that the overload period is considered where the numbers of calls initiated per minute are more than the actual capacity of the system.

The observation made over here is that, under heavy traffic load, efficiency of the network or the channel utilization and capacity of the network does not improve by using DCA instead of FCA. Although it was considered as the fact that DCA will always perform better than FCA.

Figure – Effect of the handover on FCA and DCA

In figure 4, the phenomenon observed is known as phenomenon of low capacity island [5]. Under heavy load, no benefit is achieved by using DCA, as in such a scenario both of the schemes will be utilizing capacity to the full extent. Rather DCA may perform worse than FCA. The reason is that due to dynamic channel allocation, a cell may borrow some of the frequency channels form the neighbouring cells during the low traffic period and the neighbouring cell does not get the channel back. The cell which has obtained the channel is let us say known as the lucky cell, and the cell which donated the channel and in the end, was unable to get it back is known as unlucky

cell [5]. Now during the high load traffic period, if lucky cell wants to handover the call to a neighbouring unlucky cell. But as the unlucky cell would already be out of available channels to be able to serve the call, call will be dropped. Hence under such a scenario the drop out probability of dynamic channel allocation scheme would be higher than static channel allocation algorithm.

Other simulation is to find out the effect of the arrival rate on call blocking probability. Arrival rate is the number of calls initiated per minute.

Through simulation, it is concluded that DCA performed better if the traffic load is within the range 0. 6 to 0. 9 Erlang/BS/Channel. (figure 5)

Figure – Analysis of DCA and FCA, call blocking ratio with respect to the arrival rate of the calls

During the next case it was considered that arrival rate is Poisson and the other parameters like handover rate and call holding time etc are evenly distributed all over the cell.

From the figure 6 it is clear that as probability of call blocking increases with the increase in the arrival rate of calls. Which is fairly obvious, more are the number of the users which are to be served, there is more likely a chance that some of them may not be able to get a free channel.

Figure – Performance analysis of FCA and DCA, Arrival rate of calls with respect to the over all blocking probability

Under such consideration as can be observed from the figure 6, DCA performs better than FCA, as in case of congestion in a cell, DCA can borrow channels from the neighbouring cells but in case of FCA, the scheme has no option but to reject the oncoming calls in case of congestion.

Figure 7 shows the amount of traffic carried by FCA and DCA according to the traffic load.

Figure – comparison between FCA and DCA with respect to the carried traffic under the traffic load

Figure 8 shows the performance of the channel allocation schemes when traffic imbalance is considered. It is observed that network capacity to carry data, in case of FCA, reduces significantly when data imbalance is considered. But in case of DCA, there is no significant degradation in networks capacity to carry the data. There is also significant increase in the number of calls blocked by FCA, because of the increase in the traffic imbalance. But as the carried capacity does not decrease much in case of the DCA, there is not much of the increment in number of the blocked calls.

Figure – FCA Vs. DCA, effect of the traffic imbalance on the both channel allocation techniques

Comparison of DCA and FCA in Multi Radio Network

A multi radio network is the type of the network where each node is equipped with at least two or more than two transceivers.

Fixed Channel Allocation in Multi-radio network

It is pointed out in [14], throughput and overall performance of wireless networks decreases with increased density of radios, but major reason for this problem is that these radios do not transmit the data simultaneously as the nodes are generally configured with single radios only and this factor basically limits the forwarding capacity of the network. In [15], the authors have emphasized that with the introduction of more than one NIC (Network interface cards) in wireless networks, performance of the system can be improved 6 to 7 times, instead of just doubling the performance. The same phenomenon has been confirmed in [16].

There has been much work done, in which the performance gain in wireless mesh networks with multiple interfaces is discussed as compared to single radio interface network. In [13], capacity gain between single radio, dual radio and multi-radio wireless mesh networks is compared and realistically the gain achieved by having multiple radio interfaces in the network has been discussed.

Apart from that, in [17], authors have proposed that with implementation of multi-radio Diversity approximately 2. 3 times performance gain is measured in the single radio network.

Under the multi-radio scenario, one important factor is to consider proper channel assignment. Each of the radios should be tuned to a frequency through which the throughput of the whole network is maximized. The introduction of multiple radios is not without the trade off of increased complexity of channel assignment schemes and the traffic allocation methods [20] and apart from that, more work is done in this domain. In [10],

[8], [19], the authors have proposed some approaches to get maximum possible throughput by different channel assignment algorithms.

The concept of the Static Channel Allocation in this section is extended to Wireless Mesh Networks, as before the start of the operation in the wireless mesh networks the channels are properly allocated and then till the end of the operation, the channel assignment does not change. In this section, multi-radio wireless mesh network is considered and it is observed that how by having multiple radio interfaces the performance of the network improves.

Figure – Performance of the FCA algorithms with 3 channels

Figure 9 shows the impact of the different algorithms for the channel allocation in the three channel scheme [8].

Figure – performance of the FCA algorithms with 12 channels

Figure 10 shows the impact of the different algorithms for the channel allocation in the twelve channel scheme [8].

Figure 11 shows that with different channel allocation algorithms, how the increment in number of interfaces per node impacts the performance of network. In all algorithms it is observed that with the increase in number of radio interfaces per node, throughput of wireless networks improves [9].

Figure – FCA algorithm comparison with different number of radio interfaces per node

Figure – effect of increased number of interfaces per node on the over all normalized broadcast latency

In figure 12, it is shown that with different channel allocation schemes for multi-interface wireless mesh network, normalized latency for broadcast decreases with the increase in number of radio interfaces per node [9].

In figure 13, it is simulated that with the increase in the number of interfaces per node, there is not an unlimited increment in capacity utilization. Multi radios are used so that in a network there could be as many concurrent transmissions as possible. But even this has a limit to it. In [10], it is shown that after achieving the maximum level of capacity utilization, even after by adding more number of radio interfaces in a network, no advantage is gained.

Figure – capacity degradation with increase in the number of radio interfaces per node

Figure – Effect of the number of channels and multiple radio interfaces on the throughput

In figure 14, it is shown that as long as the number of the available channels in a cell; are more than the number of interfaces per node, with increase in number of radios per node, throughput of the network will increase [11].

Figure – throughput increment of a network by increased number of the interfaces per node

In figure 15, it is shown that under a proper channel assignment and routing method, with more number of interfaces per node, the throughput of the system improves considerably [12].

In [13], as shown in figure 16 and 17, performance of fixed channel allocation scheme is compared in detail with respect to single radio network and the multi-radio network.

Figure – overall network capacity increment with more number of radio interfaces present at each node

In figure 16, it is proved that the capacity of the overall system improves with the usage of multiple radios per node.

Figure – capacity of each AP with multiple interfaces per node – Comparison between single radio to the multiple radios

In figure 17, per Access Point capacity is simulated to have comparison between multi-radio interface per node and single radio interface per node.

Dynamic Channel Allocation in Multi-radio Network:

There has been little work which proves the introduction of multiple interfaces while using the Dynamic Channel Allocation provides any performance up-gradation.

Analytically it is assumed that, as the introduction of multi-interfaces in wireless mesh networks improves performance, similarly the performance of

networks using Dynamic Channel Allocation can be improved by introducing more than one interface on a single node.

Some of the analysed parameters, which show the relative improvement in performance, are listed below:

Parameter – I: Improvement in the throughput of the system:

In a single radio cognitive network, as shown in figure 18, the node D has two data packets of equal size in its internal queue, one for node C and one for node. Nodes E and C are at the equal distance " d" from the node D but are tuned at different channels. In this particular case each packet will take time " t" to reach the destination. Even if we neglect the switching time, cognitive radio present at D will take to switch from one channel to the other channel, the time taken to completely transmit both of the packets will be t+t = 2t.

Figure – Single Radio Network

Now even if the same network topology is considered but now consider that each of the nodes is equipped with two interfaces (figure 19). Node D will be able to transmit both of the packets simultaneously to node C and node E, considering that interface 1 is tuned to the channel on which communication with node E is possible and interface 2 is tuned to the frequency over which communication with node C is possible. In this case there will be no delay caused by the switching of the channel.

Figure – Multi-interface radio network

Figure – Effect of channel switching

Conclusion: The transmission time is decreased with the factor of " N", where N is the number of interface each of the node will have. Throughput is improved with the factor of " N".

Parameter – II: Latency of the network will decrease:

With the introduction of the multiple interfaces in the cognitive radio network, latency of the network will decrease.

Figure – Multi-hop Single interface Wireless Network

Initially considering the multi-hop scenario, considering an intermediate node, it has to receive an incoming transmission on channel 1 and then it has to tune its radio to the channel 2 to be able transmit the received transmission to the destination node. Latency of such network will consist of:

Transmitting time of packet over channel 1 from source node to intermediate node: t1

Transmitting time of packet over channel 2 from intermediate node to destination node: t2

Switching time required for the interface on intermediate node to switch from channel 1 to channel 2: t3

Hence the total latency of such a system will be: t1+ t2+ t3

Figure – Multi-hop Multi interface Wireless Network

Now comparing the previous scenario with the one in which each of the node is equipped with at least two interfaces. Now on the intermediate node interface 1 will be tuned to channel 1 and interface 2 will be tuned to channel 2. If there is an incoming transmission on channel 1 and it is to be transmitted to the channel 2, the total latency will be:

Transmitting time of packet over channel 1 from source node to intermediate node: t1

Transmitting time of packet over channel 2 from intermediate node to destination node: t2

Hence the total latency of such a system will be: t1+ t2

The switching time will not be considered over here; hence comparatively the latency is decreased with the introduction of another interface on the cognitive radio node.

Conclusion: The latency factor is dependent on switching time of the cognitive radio. This factor comes into effect with more dominance with increase in the number of hops in the multi-hop network. Latency can be greatly reduced with the introduction of multi interfaces on the cognitive radio network.

Parameter – III: Connectivity of the network will improve:

The probability of isolation of any node in a network will be reduced with the introduction of the multi-interfaces in the cognitive radio network.

Figure – Single interface node with the available channels

Considering the scenario, in figure 23, where a secondary network has four channels available for its utilization, now for a given condition, all radio interfaces are tuned to either one of the channel 1, 2 or 3. If a single interface chooses channel 4, it will be isolated from the rest of the network. Assuming that the probability of opting for such a channel is p then the overall probability of getting a node isolated from the rest of the network will be p.

Figure – Multi-Interface node with the available channels

Now for multiple interfaces, a node will only be separated if both the interfaces of a single node choose channel 4.

A node will be isolated if and only if:

Interface 1 chooses channel 4 AND interface 2 chooses channel 4

P2

As according to the probability rules p <= 1, so p2 < p.

Conclusion: The probability of isolating a node, is decreased with the factor of " N" [N is the number of radios] as compared to the probability of node isolation in case of single interface cognitive radio networks.

Here mutual independence among the DCA algorithms running on both of the radio interfaces is considered, but this is not generally the case. The

performance of a cognitive radio network is strictly dependent on the number of cognitive radios present in its vicinity [21].

Figure – Improvement in throughput using multiple radios

Figure – Improvement in throughput of the network with multiple radio using different number of available channels

Figure 25 and 26 shows the throughput improvement gained by the introduction of multiple radios as compared to a single radio and in both of the figures different number of available channels are considered [24].

Comparison:

Up till so far, none of the research has been carried out to find out whether any advantage is gained by deploying Dynamic Channel Allocation scheme in the multi-radio wireless network domain as compared to the implementation of the Fixed Channel Assignment algorithm. Considering the study made regarding the performance improvement gained by fixed channel allocation scheme and dynamic channel allocation scheme in multi-radio wireless network, there could be several hypotheses made.

The complexity of implementation of Dynamic Channel Allocation algorithm will be more than that of Fixed Channel Allocation algorithm. Although the same is true in case of single radio network, but in case of the Multi-radio network, the complexity increment will be more significant. The reason can be taken as if the spectrum view of a single interface of a node changes in multi-radio network, for the similar node the situation changes for the other interfaces as well [21].

The performance improvement obtained by implementation of the Dynamic Channel Allocation algorithm as compared to the Fixed Channel Allocation in the multi-radio will have similar effects as it has in the Single radio network. The same effect on the throughput of the system, data carrying capacity and the effect of the traffic load and traffic imbalance will be observed.

Another important factor that can be predicted because of the observation made via simulation figures is as the performance of the wireless network depends upon the density of the nodes in a network. As compared to the Fixed Channel Allocation Scheme, Dynamic Channel Allocation Algorithms will be more sensitive to the density of the network [23].

There will be no matter of connectivity in case the Fixed Channel Assignment Scheme is deployed on the wireless network. As before the point of operation with FCA, it is made sure that all of the nodes are connected and none of the node is left isolated. With the Dynamic Channel Allocation there will still be a small probability that a node can get isolated from the rest of the network.

In the Fixed Channel Allocation for the multi-radio wireless network the distribution of radio interfaces do not matter for the performance. But in case of the DCA, better performance can be improved if radio interface distribution on the nodes is not uniform. DCA will perform better if the first hop nodes have more number of radio interfaces than rest of the network nodes [22].

Future Work

The points raised, during this study are just concluded through observation and analytically studying the response of the Fixed Channel Allocation Algorithm in the Multi-Radio network and Dynamic Channel Allocation Algorithm in Multi-Radio Network. These observations can be further improved by using proper simulating tools.

Conclusion

In the single radio wireless network, DCA exhibits better performance than FCA. The same behaviour is predicted for the multi-radio wireless network, but with the increased complexity. And much better performance can be achieved by taking care of the distribution of the radios in the network. Still it should be considered that there will not be infinite performance gain obtained by using multi-radio network and DCA. The limitation imposed is that number of channels available to a cell should always be greater than the number of interfaces per node has.