A SURVEY ON CHANNEL ALLOCATION SCHEMES IN CELLULAR MOBILE NETWORK

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Abstract-- In wireless mobile communication systems, radio spectrum is a limited resource. However, efficient use of available channels will improve the system capacity. The role of a channel assignment scheme is to allocate channels to cells or mobiles in such a way as to minimize call blocking or call dropping probabilities, and also to maximize the quality of service. In this paper, we have described about the significance of effective frequency reusability and avoidance of channel interference in cellular mobile topology. Afterwards we have presented all the available channel allocation schemes and made a comparative and simulative analysis towards a proficient channel assignment strategy on which the research will carry on.

Keywords-- Channel Allocation, frequency reuse, Channel interference, handoff, Channel borrowing.

I. INTRODUCTION

A cellular network provides cell phones or *Mobile Stations* (MSs) with wireless access to the *Public Switched Telephone Network* (PSTN). The service coverage area of a cellular network is divided into many smaller areas, referred to as *cells*, each of which is served by a *Base Station* (BS). The BS is fixed and it is connected to the *Mobile Telephone Switching Office* (MTSO), also known as the *Mobile-Switching Center* (MSC). An MTSO is in charge of a cluster of BSs and it is, in turn, connected to the PSTN. With the wireless link between the BS and MS, MSs such as cell phones are able to communicate with wired phones in the PSTN. Both BSs and MSs are equipped with a transceiver. [Figure-1] illustrates a - typical cellular network, in which a cell is represented by a hexagon and a BS is represented by a triangle. The frequency spectrum allocated for cellular communications is very limited. The success of today's cellular network is mainly due to the frequency reuse concept. This is why the coverage area is divided into cells, each of which is served by a BS. Each BS (or cell) is assigned a group of frequency bands or *channels*. To avoid radio co-channel interference, the group of channels assigned to one cell must be different from the group of channels assigned to its neighboring cells. However, the same group of channels can be assigned to the two cells that are far enough apart such that the radio co-channel interference between them is within a tolerable limit. Once the MTSO knows the residing cell of the MS, a channel is assigned to the cell for the call. If a call is in progress when the MS moves into a neighboring cell, the MS needs to get a fresh channel from the BS of the neighboring cell so that the call can continue. This process is called *handoff*. The channels are shared by MSs located in the cell. Multiple access methods and Channel Allocation Schemes (CASs) are used to share and allocate the channels in a cell.

To address channel assignment or allocation techniques in cellular networks, we should look at this problem from the point of view of a user. For the user it is not important how many channels are available or how they are allocated. If a user dials a number and hears a voice message that all the channels in this route are busy, please try after sometimes, then the ultimate result is the disappointment of user on the service provider. The call blockage depends on the number of available channels and traffic load. Service providers aim to keep the call blockage percentage at around 2%. As the number of subscribers increase, one way to satisfy all customers is to use more efficient channel allocation techniques to cope with the situation.

Therefore service providers use a variety of proprietary algorithms for channel allocations. These techniques can be divided into four main categories that are covered in this paper in upcoming section.

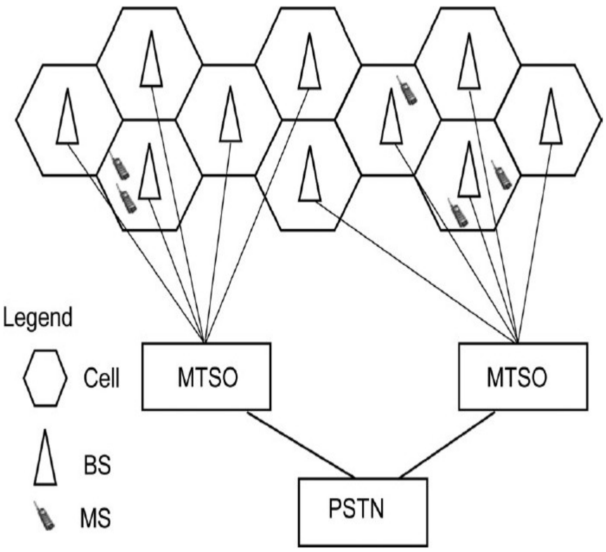

Figure1. Typical cellular network

II. FREQUENCY REUSE

Cellular topology is a special case of infrastructure multi-BS network configuration that exploits the frequency reuse concept. Radio spectrum is one of the scarcest resources available, and every effort has to be made to find ways of utilizing the spectrum efficiently and to employ architectures that can support as many users as theoretically possible with the available spectrum. This is extremely today in light of the huge demand for capacity. Spatially reusing the available spectrum so that the same spectrum can support multiple users separated by a distance is the primary approach for efficiently using the spectrum which we call as *frequency reuse*. Employing frequency reuse is a technique that has its foundations in the attenuation of the signal strength of electromagnetic waves with distance. For instance, in vacuum or free space, the signal strength falls as the square of the distance [1].

This means that the same frequency spectrum may be employed without any interference for communications and other purposes, provided the distance separating the transmitters is sufficiently large and their transmit powers are reasonably small. This technique has been used in commercial radio and T.V broadcast where the transmitting stations have a constraint on the maximum power they can transmit so that the same frequencies can be used elsewhere. The cellular concept is an intelligent means of employing frequency reuse. Cellular topology is the dominant topology used in all large-scale terrestrial and satellite wireless networks. The concept of cellular communications was first developed at Bel Laboratories in the 1970 to accommodate a large number of users with a limited bandwidth [2].

III. CHANNEL INTERFERENCE

Two types of interference are important in a cellular architecture. The interference due to using the same frequencies in cells of different clusters is called as *co-channel interference*. The cells that use the same set of frequencies or channels are called *co-channel cells*. The interference from different frequency channels used within a cluster whose side-lobes overlap is called *adjacent channel interference***.** The allocation of channels within the cluster and between clusters must be done so as to minimize both of these [3].

IV. CHANNEL ALLOCATION SCHEMES

The channel allocation schemes can be categorized into four main classes: fixed channel allocation (FCA), dynamic channel allocation (DCA), hybrid channel allocation (HCA) and flexible channel allocation (FlCA).

A. Fixed Channel Allocation

In these schemes a set of channels are permanently assigned to each cell for its exclusive use. Here a definite relationship is assured between each channel and each cell in accordance with the co-channel reuse constraint [4]. The total number of available channels i.e. the spectrum is divided into sets and the minimum number of channel sets (N) required to serve the entire coverage area is related to the reuse distance.

In case of uniform traffic, same number of channels is allocated to each cell and it remains constant with time. This is an optimum channel allocation strategy.

But in case of non-uniform traffic, different set of channels may be allotted to different cells [5]. The cells with higher traffic load should somehow use the free channels available in low traffic cells. We need to include call blockage probability as a criterion for the channel allocation algorithm. Because the relation between the number of channels and call-blockage probability is a complex function, this algorithm becomes significantly more complex.

Algorithms that distribute channels among the cells according to their traffic load have been investigated. For example, a non uniform compact channel allocation algorithm is discussed in [5].The results of simulations show that the algorithm provides better call-blockage probability in the system.

Channel Borrowing Techniques in FCA

The FCA, a heavily loaded cell will borrow channels from the neighboring cells subject to non-interference with any existing communication sessions ([5] [6] [7] [8] [9]). In other words the high traffic cells borrow channels for low traffic cells which are referred to as *Channel borrowing techniques* [10].

There are two methods to borrow channels: *temporary channel borrowing* and *static channel borrowing*. In temporary channel borrowing, high traffic cells return the borrowed channels after the call is completed. In static channel borrowing, channels are non-uniformly distributed among cells according to the available statistics of the traffic and changed in a predictive manner.

A number of methods for selecting free channels from a highly loaded cell for borrowing by another cell are summarized in [10]. These methods either make all channels available for borrowing which is known as *simple borrowing schemes* or they partition the channels into borrowable and non borrowable which are called as *hybrid borrowing schemes*. Simple borrowing schemes are found to be better under light or moderate traffic loads. A quantitative comparison of some of these techniques is provided in [11].Channel borrowing schemes; however require additional computational complexity and frequent switching of channels. They may also affect handoff strategies.

In short-term temporal and spatial variations of traffic in cellular systems, FCA schemes are not able to attain high channel efficiency.

B. Dynamic Channel Allocation

In these schemes all the channels are kept in a central pool and are assigned dynamically to the requesting cells as new communication request arrives in the system and after the session is over, the channel is returned to the central pool ([12][13]). In DCA scheme, a channel can be used in any cell provided that signal interference constraints are satisfied. The DCA scheme can be implemented in a centralized or distributed manner.

In centralized DCA scheme, a central server maintains the channel pool, which is responsible for the channel allocation. This scheme seems to be near optimal under non-uniform traffic load in different cells but at the expense of a highly centralization overhead and also fault-prone ([14][15]).

Distributed DCA techniques are further divided into two classes: *cell-based and measurement-based techniques.* Cell-based techniques require each BS to maintain a table of variable channels in its vicinity and based on this table, the BS decides and assigns the channel to the users in its cell. This technique is very efficient, but the expensive incurred is additional inter-BS communication traffic, which increases with the traffic in a cell. To avoid this situation, signal-strength or measurement-based techniques are evolved. Here each BS makes the channel assignment based on received signal strength of the mobiles in its vicinity. In such schemes all channels are available to the BS, and the BS makes its decision based on the local information without any need to communicate with other BSs. These schemes are self organizing, simple, efficient and fast, but they suffer from additional co-channel interference which may result in channel interruption and network instability ([16][17][18])9.

C. Hybrid Channel Allocation (HCA)

In this scheme, a mixture of FCA and DCA schemes are used to optimize the channel allocation. These types of schemes are proposed as a mixture of FCA and DCA [19] in which total number of channels available for services are divided into fixed and dynamic sets. The fixed set contains the number of primary channels that is exclusively assigned for the use of particular cell only as in FCA schemes. The primary channels are preferred to be used in the respective cells. All the cells share the second set of channels in the system to increase the flexibility. When a communication session requires a channel in a cell in which all the primary channels are busy, a channel from the dynamic set is assigned to the cells using the DCA scheme and the assigned channel is returned to the dynamic set soon after the communication session is completed.

D. Flexible Channel Allocation (FlCA)

In the flexible channel assignment scheme, the set of available channels is divided into fixed and flexible sets. The channels in the fixed sets are assigned to the cells following FCA scheme which are sufficient for light traffic load and the flexible channels are assigned to those cells whose channels have become inadequate under increasing traffic load either in scheduled as predictive manner[20].

V. COMPARISON OF THREE CLASSES OF DCA ALGORITHMS

Table-1 compares all three classes of DCA algorithms. Centralized DCA strategies do provide optimal or near optimal channel allocation.

TABLE I
Comparison of Three Classes of DCA Algorithms

Advantages	
Centralized DCA	Near optimum channel allocation.
Cell-based Distributed DCA	Near optimum channel allocation.
Measurement-based Distributed DCA	Suboptimum channel allocation, simple assignment algorithm, use of local information, minimum communication between BSs, Increase system capacity, efficiency, radio coverage, fast real time processing, adaptive to traffic changes
Disadvantages	
Centralized DCA	High-centralized overhead
Cell-based Distributed DCA	Extensive communication between BSs
Measurement-based Distributed DCA	Increased co-channel interference, deadlock probability, instability

However, they require a lot of computational signaling effort because the centralized location has to be aware of available channel and the necessary parameters required making an optimum decision on which channel to allocate to an incoming call. These parameters could be how channels are allocated in co-channel cells, what are the signal strength values for the channel under consideration, what is the expected traffic load in and around the region, and so on. Also, because decision mechanism is centralized, it is not robust and a failure here could lead to an entire system wide shutdown.

In that case DCA strategies are better. Cell-based distributed DCA strategies also can allocate channels optimally because BSs can communicate with each other to obtain knowledge of the entire system. Although the BSs make the decision to allocate channels, the need for frequent communication and update between BSs, is a disadvantage. Signal-strength or measurement-based DCA strategies do not provide optimal allocation of channels. Such schemes do, however, provide some capacity increases and are implemented in digital cordless systems like *Digital enhanced cordless telephone*.

VI. COMPARISON OF FCA, DCA & HCA

Overall, DCA techniques have shown 30 to 40 percent performance improvements over the simple FCA techniques [21]. Table-2 compares between FCA and DCA.

Under low to moderate traffic loads, DCA strategies perform far better than FCA techniques. Because DCA is based on random arrivals of mobiles and random allocation of channels to them, unless maximizing the “packing” of channels is an optimization criterion, it is likely that distances larger than what is required may separate co-channels. This will prevent channels from being reused as often as possible, resulting in less capacity in larger loads. DCA however, reduces the fluctuations in the cell blocking probabilities, as well as forced call termination. FCA strategies require a lot of “offline” effort in frequency planning. DCA strategies need plenty of effort in real time for channel allocation.

Indeed, hybrid channel allocation strategies have also been investigated. The total number of channels is portioned into fixed and dynamic sets. The ratio of fixed to dynamic channels becomes important in the performance of the system. HCA schemes have been shown to perform better than FCA schemes for load increases up to 50% [10].

TABLE II
Comparison of FCA, DCA & HCA

Attribute	Fixed Channel Allocation	Dynamic Channel Allocation
Traffic Load	Better under heavy traffic load	Better under light/moderate traffic load
Flexibility in	Low	High

Channel Allocation		
Reusability of Channels	Maximum possible	Limited
Temporal and Spatial Changes	Very sensitive	Insensitive
Grade of Service	Fluctuating	Stable
Forced Call Termination	Large probability	Low/moderate probability
Suitability of Cell Size	Macro cellular	Micro cellular
Radio Equipment	Covers only the channels allocated to the cell	Has to cover all possible channels that could be assigned to the cell
Computational Effort	Low	High
Call Setup Delay	Low	Moderate/High
Implementation Complexity	Low	Moderate/High
Frequency Planning	Laborious and complex	None
Signal Load	Low	Moderate/High
Control	Centralized	Centralized, decentralized or distributed

VII. CONCLUSION

Attempt has been made to survey all types of channel allocation mechanisms. The main objective of channel allocation techniques is to stabilize the fluctuations in the probability of call blockage over the entire coverage area of a network over time. An efficient and effective comparison among various channel allocation schemes is made. Overall, DCA techniques have shown 30 to 40 percent performance improvements over the simple FCA techniques. A unified framework for comparing all kinds of strategies of FCA and DCA is not available and it is hard to say which of these schemes is actually beneficial. In addition, DCA schemes that jointly optimize power control and handoff strategies have also been proposed. HCA schemes have been shown to perform better than FCA schemes for load increases up to 50%. Therefore the research will continue to develop an efficient channel allocation algorithm based on HCA scheme in very near future.

REFERENCES

[1] Susil Kumar Sahoo and Prafulla Kumar Behera, "Path loss- A parameter that affects channel performance in mobile communication," *National Journal of Computer Science and Technology*, Vol. 3, pp. 34-36, July-Dec 2011.

[2] V. H. MacDonald, "The cellular concept," *The Bell System Technical Journal*, Vol. 58, No. 1, pp. 15-41, January 1979.

[3] Xing Zhang and WeihuaZhuang, "A Channel Sharing Scheme for Cellular Mobile Communication," *Wireless Personal Communications*, Vol. 9, pp. 149-163, 1999.

[4] Leonard Schiff, "Capacity of Three Types of Common User Radio Communication Systems", *IEEE Transactions on Communication Technology*, Com-18, pp. 12-21, 1970.

[5] Ming Zhang and Tak-Shing Yum, "The Non Uniform Compact Pattern Allocation Algorithm for Cellular Mobile Systems", *IEEE Transactions on Vehicular Technology*, Vol. 40, No. 2, pp. 387-391, 1991.

[6] J. Tajima, K. Imamurra, "A Strategy for Flexible Channel Assignment in Mobile Communication Systems", *IEEE Transactions on Vehicular Control*, Vol. VT-37, May 1988.

[7] H. Sawada, H. Sekiguchi, M. Koyama, H. Ishikawa, "Techniques for increasing frequency spectrum utilization", *IECE Technical Report*, CS84-100, 1984

[8] R. Singh, S.M.Elnoubi, C. Gupta, " A new frequency channel assignment algorithm in high capacity mobile communication systems", *IEEE Transactions on Vehicular Technology*,VT-31, 1982.

[9] Ming Zhang, "Comparison of channel assignment strategies in cellular mobile telephone systems", *IEEE Transactions on Vehicular Technology*,VT-38, 1989, pp. 211-215

[10] I. Katzela and M. Naghshineh, "Channel Assignment Schemes for Cellular Mobile Telecommunication Systems: A Compressive Survey," *IEEE Personal Communications*, pp. 10-31, June 1996.

[11] S.S. Kuek and W.C. Wong, "Ordered Dynamic Channel Assignment Scheme with reassignment in highway micro cells," *IEEE Transactions on Vehicular Technology, Vol. 41, No. 3, pp. 271-276, Aug 1992*

[12] Kazunori Okada, Fumito Kubota, On dynamic channel assignment strategies in cellular mobile radio systems", *IEEE international symposium on circuits and systems*, Vol.2, 1991,pp.938-941

[13] I. Katzela, M. Naghshinesh, "Channel assignment schemes for cellular mobile telecommunication systems", *Personal Communication Magazine*, June 1996.

[14] R. Beck, H. Panzer, "Strategies for handover and dynamic channel allocation in microcellular mobile radio telephone systems", *IEEE Transactions on Vehicular Control*, 1989,pp. 329-337

[15] Donald Cox, Douglas Reudink, "A comparison of some channel assignment strategies in large mobile communication systems", *IEEE Transactions on Communications*, Vol. 20,1972, pp. 190-195

[16] C.L I, P.H.Chao, "Local packing - Distributed dynamic channel allocation at cellular bast station", *IEEE GLOBECOM*, 1993

[17] K. Okada, F. Kubota, "Performance of dynamic channel assignment algorithm with information of moving direction in mobile communication systems", *IEICE Spring National Convention*, 1991

[18] Ravi Prakash, Niranjan G. Shivaratri, MukeshSinghal, "Distributed dynamic channel allocation for mobile computing", *Proceeding of 14th ACM Symposium on principles of Distributed Computing (PODC), Ottawa, Canada*, August, 1995, pp. 47-56

[19] Tomson Joe Kahwa, NicholaosGeorgnas, "A Hybrid channel assignment scheme in largescale cellular-structured mobile communication systems", *IEEE Transactions on Communications*, COM-26,1978, pp. 782-785

[20] Jun Tajima, K. Imamura, "A Strategy for flexible channel assignment in mobile communication systems", *IEEE Transactions on Vehicular Technology*, VT-37, 1988, pp. 92-103

[21] D. J. Goodman, J. Grandhi and R. Vijayan, "Distributed dynamic channel assignment schemes," *Proc. of the 43rd IEEE Veh. Tech. Conf.*.pp. 532-535,1993