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Dynamic channel allocation for multipath cellular networks using MSWF in wireless network

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Abstract

In multi-hop cellular networks, a channel that contributes the lowest relaying delay is proposed to the current node on the path. The current node itself does not receiving on the time-slot of the proposed channel that enhance the capacity and coverage problems of cellular networks. They also allow faster and cheaper deployment of cellular networks. A fundamental issue of these networks is packet delay because multi-hop relaying for signals is involved. An effective channel assignment is the key for the reducing delay. It proposes an optimal and a heuristic channel assignment scheme, called OCA and minimum slot waiting first (MSWF) respectively, for a time division duplex (TDD) wideband code division multiple access (W-CDMA) MCN. OCA provides an optimal solution in minimizing packet delay and can be used as an unbiased or benchmark tool for comparison among different network conditions or networking schemes. However, OCA is computationally expensive and thus, inefficient for large real-time channel assignment problem. In this case, MSWF is more appropriate. Simulation results show that MSWF achieves on average 95% of the delay performance of OCA and is effective in achieving high throughput and low packet delay in conditions of different cell sizes. For improving more on quality of service we can propose channel reuse. Using FDMA and TDMA we can reuse the channels. The novel feature of the proposed technique is that co-coordinated, prioritized TDMA is supported for clusters of access points (AP's) using measurement based time slot assignments.

Keywords: Cellular network, MSWF, CSMA, OCA, channel assignment.

Introduction

An important problem in the operation of a cellular telephone system is how efficiently use the available bandwidth to provide better service to customers as many as possible. This problem becomes critical with the rapid growth of cellular telephones. Availability of multiple channels and interfaces poses the additional challenge determining efficient assignment of channels to links and interfaces. In general, the throughput problem in wireless networks entails jointly optimizing routing, channel assignment (to interfaces & links) and interference-free scheduling of links. A simple way to increase the utilization of the radio resource or enhance the cellular capacity is to divide large cells into many small cells. Each cell reuses the channel (frequency, time-slot, code). In a code division multiple access (CDMA) cellular system such as second generation (2G) CDMA or third generation (3G) wideband code division multiple access (W-CDMA) system, first considers only a static assignment of channels to interfaces. On the other hand, dynamic channel assignment offers more flexibility and improved capacity, and incurs minimal overhead using improved hardware technology. The work considers dynamic channel assignment, but for a predetermined set of paths between each source-destination pair. Second, all the prior works on throughput maximization are for simple (pair-wise) interference models, wherein the model is represented as a set of pairs of links that interfere with each other. On the other hand, the physical interference model is less restrictive and in general, yields higher capacity than pair-wise interference model in scenarios that do not use CSMA techniques (De *et al.,* 2002). Third, all the prior works on throughput maximization consider multipath routing (or predetermined single-path routing (Noor & Anpalagan, 2004) between each source-destination pair. Multipath internet works are more complex to configure, while single-path routing infrastructure has simplified routing tables. Moreover, in single-path routing, the problem of packet reordering (needed in multipath routing) does not exist. Indeed, in conventional networks (e.g., the internet), application-level flows generally use single-path routing. The simplest approach is to permanently assign channels to cells in such a way that the channel reuse constraint can never be violated even if all channels of all cells are used simultaneously. This is called a fixed assignment method. In a dynamic assignment method, in contrast, all channels are potentially available to all cells and are assigned to cells dynamically as calls arrive. If this is done right, it can take advantage of temporary changes in the spatial and temporal distribution of calls in order to serve more users. For example, when calls are concentrated in a few cells, these cells can be assigned more channels without increasing the blocking rate in the lightly used cells.

Related works

The channel assignment problem can be formulated as a semi-Markov decision process much as the elevator dispatching problem. A state in the semi-MDP formulation

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has two components. The first is the configuration of the entire cellular system that gives for each cell the usage state (occupied or unoccupied) of each channel for that cell. Fu *et al.* (2006) shown that the goal of channel assignment is to maximize channel (frequency) reuse among cells in a cellular system. Channels or frequencies can be reused among cells as long as the distance among those cells is sufficiently large such that the signal interference level does not exceed the required level. The task is to assign a minimum number of channels to every requested call such that interference constraints are satisfied. This is a classical channel assignment problem; the channel assignment problem is a switching point problem. A switching point is a position in a transmission frame at which the transmission direction reverses. For example, an uplink transmission direction is changed to a downlink transmission direction and vice versa. In an asymmetrical transmission TDD-CDMA system, improper switching point assignment may cause interference which degrades the uplink and/or downlink capacity. Three channel allocation schemes, fixed channel allocation (FCA), dynamic channel allocation (DCA) and DCA with adaptive switching point (DCA-ASP) are discussed (Li XJ and Chong PHJ, 2010)to allocate the channel. Both FCA and DCA consider only a single switching point in a transmission frame only. The switching point is set and fixed when the system is initialized. FCA assigns channels randomly to each connection without considering the channel quality. DCA assigns channels to each connection based on the channel quality. DCA-ASP (Noor & Anpalagan, 2004) supports the movement of multiple switching points to dynamically adjust the bandwidth to suit the traffic for uplink and downlink. In our model, the system operates synchronously in a time-slotted model. In any time slot, a set of non-interfering links is active and each interface is assigned a channel. In the static channel assignment model, the assignment of channels to interfaces is fixed across time slots, while in the dynamic assignment model; an interface can choose different channels in different time slots. Each active link (u, v) uses a pair of interfaces (assigned the same channel) at u and v. We assume uni-cast transmissions; thus, an interface can be used by at most one link. However, in a time slot, a link (u, v) may support multiple simultaneous transmissions using multiple pairs of interfaces. Thus, in a time slot, a multi-set of links may be active, with each instance of a link associated with a different pair of interfaces. The joint routing, channel assignment, and scheduling (JRCAS) problem to maximize throughput can be informally described as follows: Input: A wireless network graph, the interference model and a set of source-destination pairs. Output: An interference-free schedule of link transmissions into time slots that guarantees maximum total data rate between the given source-destination pairs. By default, we assume multipath routing. In either case, the flows must observe link-capacity, flow conservation, and "interface "constraints.

Notes: 1). Design of a link schedule entails assignment of channels to link instances. 2). The JRCAS problem is a generalization of the classic multi-commodity flow problem (Aggelou & Tafazolli, 2001) with additional resources (channels & interfaces), constraints (interference & interface) and outputs (link schedule & channel assignment).

Channel configuration model

Network interference degree is the maximum interference degree of any link, where the interference degree of a link (u, v) is the number of links that interfere with (u, v) but not with each other. In other words, network interference degree is the size of the maximum independent set in the sub-graph induced by the neighbours of any vertex in the conflict graph. Network interference degree is generally dependent only on the interference model (independent of the network topology). For example, the simple node-exclusive (primary) interference model has a network interference degree of 2, while the uniform range secondary interference model which approximates IEEE 802.11 DCF has a network interference degree of 8 (Li & Chong, 2002). A link schedule is a specification of a certain number of time slots. For each time slot, we specify a multi-set of active links with a channel assigned to each link instance.

A valid link schedule must satisfy two constraints: 1) The link instances active in the same time slot do not interfere and 2) the number of different channels incident on any node u in a time slot is less than v. A call can be considered as a connection, traffic flow, or session. Each node on the path is assigned a channel for the connection. To model an initiation point of a connection in a source node, we define a virtual point called source point s. A source node may have several source points, each point for a different connection. A fundamental issue of these networks is packet delay because multi-hop relaying for signals is involved. An effective channel assignment is the key to reducing delay. It propose an optimal and a heuristic channel assignment scheme called OCA and minimum slot waiting first (MSWF) respectively, for a time division duplex (TDD) wideband code division multiple access (W-CDMA) MCN. OCA provides an optimal solution in minimizing packet delay and can be used as an unbiased or benchmark tool for comparison among different network conditions or networking schemes.

Channel assignment scheme

Herein presented optimal channel assignment scheme (OCA) and a heuristic scheme called MSWF for a TDD W-CDMA MCN. Both schemes are designed based on the design goals described before. The schemes reside and are executed in a network controller, such as the

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radio network control (RNC) in the 3G UMTS (Holma & Toskala, 2004). Each network controller connects a number of BSs. We assume RNC has the global information of the position, data rate, route, and channel assignment of all mobile nodes. Optimal Channel Assignment given a set of relaying paths, the task is to find a channel assignment to minimize the total packet relaying delay and to ensure that no signal collision, channel conflict, or co-time-slot conflict occurs. To solve this problem, we formulate the OCA scheme as an Integer linear program as follows:

- An integer program for OCA, we start with the set of relaying paths from source nodes to the BS found by the routing algorithm deployed in the system.
- Let V be the set of (virtual) points that determine the relaying paths such that no two paths intersect except at the BS.
- Let S be the set of source points, and R the set of relaying points.
- Set V may correspond to the same physical node. For e.g., in Fig. 1, node A contains the source point s1 and the relaying point r1.

QoS depends upon the network reach ability, cell capacity, effectiveness of the channel assignment schemes and delay depends on the effectiveness of the channel assignment scheme. Here, when the number of relaying is small, many source nodes do not reach the base station due to lack of relaying paths. Hence throughput and delay in MSWF is little. The cell radius of 390 m results in higher throughput than 250 m because later has larger coverage, and hence more source node can reach the base station (BS). The MOSEK optimization software, http://www.mosek.com, Feb. 2009.

Minimum slot waiting first (MSWF)

We herein, propose a heuristic channel assignment scheme, called MSWF, which provides a good approximation to the optimal solution offered by OCA. The problem for MSWF is an online version of the problem of OCA as follows:

Given a relaying path, the task is to find a channel assignment for the path to minimize the packet relaying delay (time-slot waiting time) and ensure that no signal collision, channel conflict or co-time-slot conflict occurs. Unlike OCA, which solves an offline global optimization problem of minimizing the delay of the system, MSWF is a greedy algorithm providing a locally optimal solution, focusing on minimizing delay for the packets on the path of a new call. The information about other nodes, which do not interact or interfere with the nodes on the new path, does not need to be processed. The channel assignments of existing paths are not affected. The design of MSWF is based on two principles: 1. Eliminate conflicting channels and 2. Select channels which contribute minimum relaying delay (time-slot waiting time).

The algorithm of MSWF

MSWF mainly consists of two phases: the proposing phase and the checking phase. When assigning a channel to a node (virtual point) on a relaying path, a channel which contributes minimum relaying delay (time-slot waiting time) is proposed for the node. We call the node the current node and the selected channel the proposed channel. The channel is checked for channel conflicts based on four rules: a, b, c and d. Rules a and b is used for checking co-timeslot conflicts whereas rules c and d are used for checking co-channel channels. If no rules are violated, the proposed channel is accepted (selected); otherwise, the channel is eliminated. The following are the two phases:

Proposing phase: A channel that contributes the lowest relaying delay is proposed to the current node on the path.

Checking phase: *Rule a:* The current node itself is not receiving on the time-slot of the proposed channel. *Rule b:* The next-hop node is not transmitting on or temporary assigned with the time-slot of the proposed channel. *Rule c:* Nodes on the other routes, having their transmission zones in which the next-hop node falls are not transmitting on the proposed channel. *Rule d:* Nodes that are in the transmitting zone of the current node are not receiving on the proposed channel.

Performance evaluation

Here we consider the performance of MSWF with respect to OCA and the single-hop case at different conditions in terms of number of time-slots, number of hop counts, nodal densities, and cell sizes 5.1 simulation model and parameters. Our simulation model is a single source and several destination to allocate the channel. The number of relaying nodes varies from 0 to 160 in increments of 40. We separate the role of source node and relaying node so that the case in which no mobile nodes are willing to relay signals can be captured. The different number of relaying nodes is used to model different network densities and traffic patterns. All the nodes are uniformly distributed in a circular region with a radius of 1,100 m centered at the BS.

Scenario 1 (Small number of available channels): In this scenario, the transmission range of the BS and mobile nodes is 250 m with cell capacity of 1,035 kbps. Each TDD data transmission frame is 3.33 milliseconds long and has 5 time-slots. This frame size is 1/3 of the standard data transmission frame size, which is 10 ms and 15 time-slots, in the WCDMA standard (Holma & Toskala, 2004). All 5 time-slots are assigned for the BS uplink transmission. Each time-slot can be assigned maximum five codes. Thus, there are 25 channels (time-slot code pairs). Each code corresponds to a data rate of 44.4 kbps, which is 3 times 13.8 kbps (the data rate of

Fig. 1. Virtual points for the relaying paths correspond to the topology.

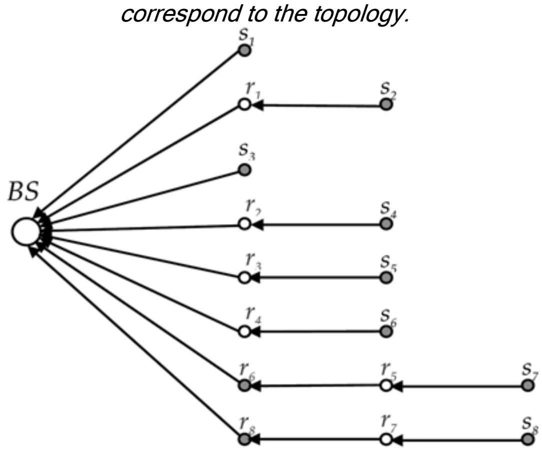

Fig. 3. A single-cell model.

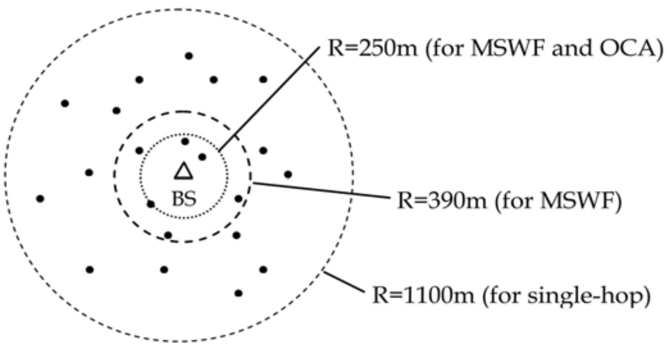

Fig. 4. Per-hop packet delay.

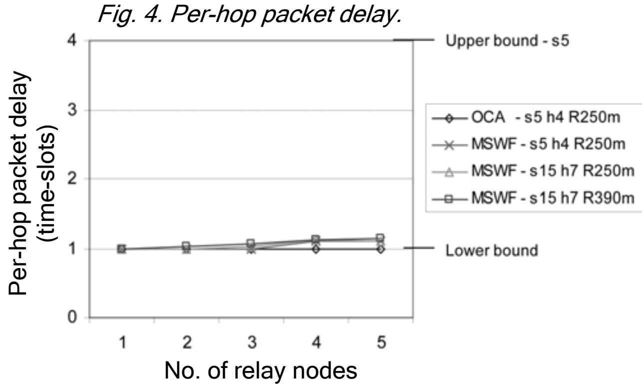

Fig. 5. C.O.V. of per-hop packet delay.

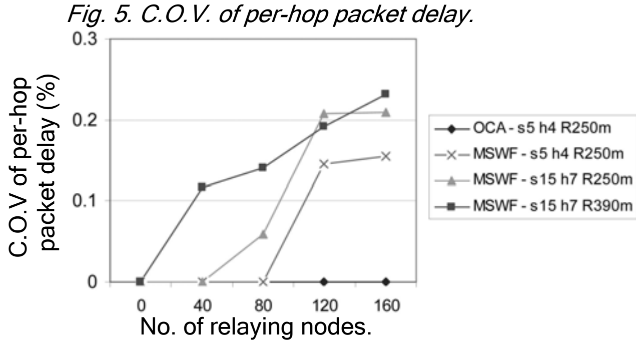

Fig. 2. Channel allocation procedure.

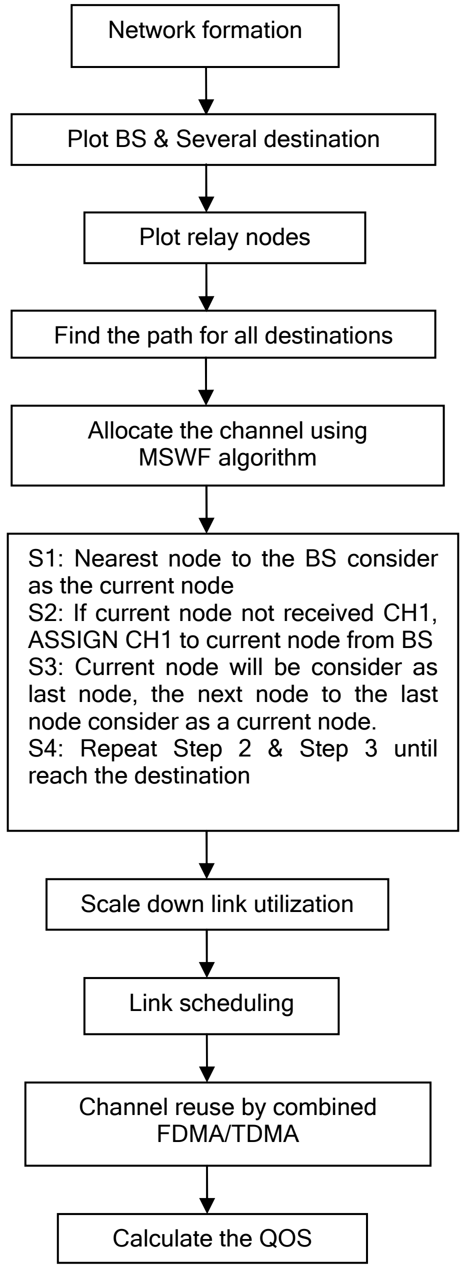

Fig. 6. Cell throughput.

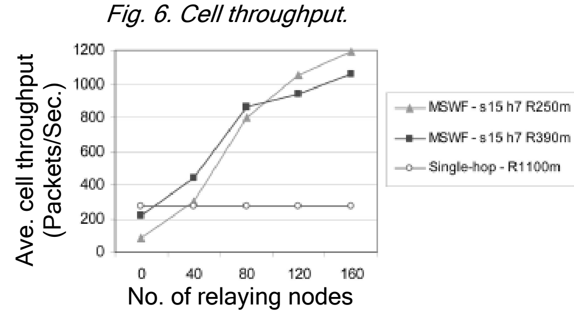

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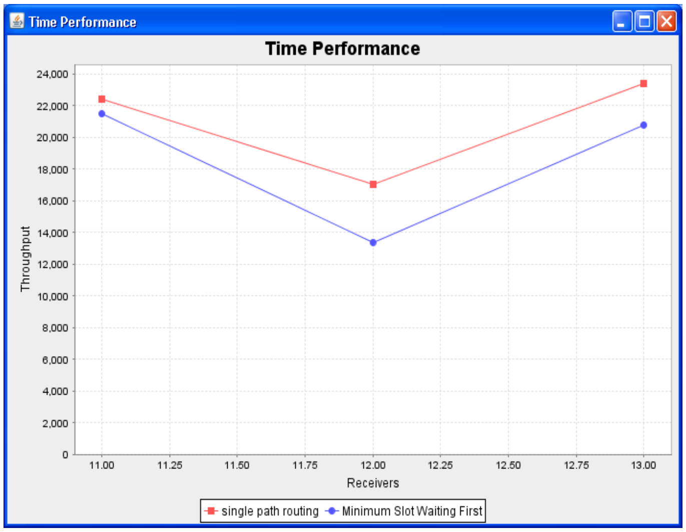
Fig.7.Throughput value comparison for Single Path routing Vs MSWF



one code with spreading factor 16 in the WCDMA standard) (Holma & Toskala, 2004). Each call uses one code at a constant bit rate. The maximum number of hops is set to 4 to avoid excessive delay. The number of source nodes is 45 which is larger than 25. Note that a relatively large number of source nodes are used because a small hop count is used. Thus, even though the network density is high, there are source nodes not able to reach the base stations to use the available channels. In this setting, there is enough demand reaching the BS to establish a congested condition to test the effectiveness of the schemes.

Scenario 2 (Large number of available channels): In this scenario, for MSWF case, the transmission ranges (cell size) of the BS are 250 and 390 m with cell capacity of 1,035 and 828 kbps respectively, whereas the transmission range of mobile nodes is 250 m. For the

Table 1. Simulation parameter.

	Scenario 1	Scenario 2		
	OCA/MSWF - s5 h4	MSWF - s15 h7	MSWF - s15 h7	Single-hop
BS/ mobile range	250m	250m	390m	1100m
BS/ mobile capacity	1035 kbps	1035 kbps	828 kbps	207 kbps
Time-slots/frame	5	15	15	15
Time-slots (uplink)	5	13	13	13
Codes/time-slot	5	5	4	1
Max. hop count	4	7	7	1
Data rate per code	44.4 kbps	13.8kbps		
No. of source nodes	45	70		
Call request rates	0.5 calls/min.			
Call holding time	1 min.			
Antenna	directional antenna with beam angle 45°			
Simulation duration	15 mins.			

single-hop case, the transmission range of the BS is 1,100 m with cell capacity of 207 kbps. Each TDD data transmission frame is 10 ms long and has 15 time-slots according to the WCDMA standard (Holma & Toskala, 2004). The number of uplink time-slots and the number of downlink time-slots are 13 and 2 respectively. For MSWF-R250 m case, each time-slot can be assigned five codes. Thus, there are 65 uplink channels. For MSWF-R390 m case, each time-slot can be assigned with four codes and there are 52 channels. Each code corresponds to a data rate of 13.8 kbps (Holma & Toskala, 2004). For the single-hop case, each time-slot can be assigned with maximum 1 code in this model; our focus is on channel assignment. We assume there is a routing protocol to provide relaying paths. We assume nodes to be static (or with limited mobility) because we focus on studying the performance of channel assignment schemes.

Simulation results

In this section, we first discuss the simulation results of MSWF on per-hop packet delay (Fig. 4) and C.O.V. of per-hop packet delay with respect to that of OCA and various parameters (Fig. 5). Then, we study the performance of MSWF with respect to the single-hop case and different cell sizes in terms of throughput and packet delay. In the Fig 6, the s15 h7 represents 15 time-slots per frame and 7 hop count limits, respectively. Simulation parameters are stated in Table 1. Considering the optimality characteristic of OCA for MSWF cases, the number of relaying nodes has more influence on the per-hop packet delay. When the network is sparse to medium, most source nodes cannot reach the BS to use the available channels. More channels are available for selection and fewer paths are set for relaying signals. Thus, fewer co-channel conflicts occur and it is relatively easier to resolve the channel conflicts to achieve perfectly pipelined condition of time-slot assignment along the input paths. Thus, the per-hop packet delay is equal to or close to the lower bound, one. Among the MSWF cases, the larger the number of time-slots per frame and the number of hops, the higher the per-hop packet delay and may cause confusion. Although MSWF has a higher delay than that of the single-hop case, with the consideration of the fact that MSWF has more number of hops, MSWF still achieve a good performance in terms of minimizing delay. In fact, the delay difference between the MSWF cases and the single-hop case is approximately equal to the average number of hops per path times the per-hop packet delay lower bound. This demonstrates the effectiveness of MSWF in minimizing delay. For MSWF cases, when the number of relaying nodes is small, i.e., when the nodal density is low, many sources nodes still cannot reach the BS due to the lack of relaying paths. Thus, the increase in throughput and delay of MSWF is little. The MSWF case with cell radius of 390 m has a higher throughput than the case with cell radius of 250 m because the former has a larger coverage and hence more source nodes can reach the BS. Fig .7 indicates the throughput value comparison for Single Path routing Vs MSWF.Throughput value for MSWF is better than Single Path routing to allocate the channel.

Conclusion

We propose an optimal channel assignment scheme (OCA) and a heuristic channel assignment scheme (MSWF) to minimize the delay in a TDD W-CDMA MCN or any TDD MCN. OCA provides an optimal channel assignment solution in terms of minimum packet relaying delay and can also be used as an unbiased or benchmark tool for performance comparison of different network conditions and networking schemes. However, OCA is computationally expensive and may be inefficient for large-scale real-time channel assignment problems. MSWF is a good approximation solution to OCA in terms delay and processing time. Simulation results also show that MSWF achieves (on average) 95% of the delay performance of OCA. MSWF has a low per-hop packet delay which is close to the per-hop lower bound of packet delay. It achieves high throughput and low delay as compared to the single-hop case and is applicable to different cell sizes. Channel assignment is only one of the components needed to realize the implementation of MCNs. Other functions such as mobility management, routing, power control, power efficiency, quality of service management, and security still need to be addressed.

References

1. Aggelou GN and Tafazolli R (2001) On the relaying capacity of next generation GSM cellular networks. *IEEE Personal Comm.* 8(1), 40-47.
2. Al-Ayyoub M and Gupta H (2010) Joint routing, channel assignment and scheduling for throughput maximization in general interference models. *IEEE Trans. Mobile Computing*. 9(4), 553-565.
3. Al-Riyami M, Safwat AM and Hassanein HS (2005) Channel assignment in Multi-Hop TDD W-CDMA cellular networks. Proc. *IEEE Intl. Conf. Comm*. (ICC '05). pp: 428-1432.
4. Bre´laz D (1979) New methods to colour the vertices of a graph. *Comm. ACM*. 22(4), 251-256.
5. Chafekar D and Maratge M (2008) Approximation algorithm for computing capacity of wireless networks with SINR constraints. Proc. IEEE INFOCOM.
6. De S, Tonguz O, Wu H and Qiao C (2002) Integrated cellular and ad hoc relay (iCAR) systems: Pushing the performance limits of conventional wireless networks. Proc. IEEE Hawaii, Int. Conf. System Sci. (HICSS '02), pp: 3899-3906.
7. Fu X, Bourgeois AG, Fan P and Pan Y (2006) Using a genetic algorithm approach to solve the dynamic channel-assignment problem. *Int. J. Mobile Comm.* 4(3), 333-353.
8. Holma H and Toskala A (2004) WCDMA for UMTS, radio access for third generation mobile communications. 3rd ed. John Wiley & Sons.
9. Li XJ and Chong PHJ (2008) A dynamic channel assignment scheme for TDMA-based Multi-hop cellular networks. *IEEE Trans. Wireless Comm.* 7(6), 1999-2003.
10. Li XJ and Chong PHJ (2010) Performance analysis of Multi-hop cellular network with fixed channel assignment. *Wireless Networks.* 16, 511-526.
11. Li XJ, Seet BC and Chong PHJ (2008) Multi-hop cellular networks: Technology and economics. *Computer Networks.* 52, (9), 1825-1837.
12. Lin YD and Hsu YC (2000) Multihop cellular: A new architecture for wireless communications. Proc. IEEE INFOCOM. pp: 1273-1282.
13. Noor L and Anpalagan A (2004) Dynamic channel allocation in TDD-CDMA systems. *IEEE Canadian Rev.* pp:9-11.
14. Third generation partnership project (3GPP) (1999) Technical specification group radio access network. Opportunity driven multiple access (ODMA), Sophia Antipolis, Valbbonne (3G TR 25.924 Version 1.0.0).