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DEVELOPMENT OF MEDIUM ACCESS CONTROL SCHEME FOR MULTIHOP CELLULAR NETWORKS

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ABSTRACT

Cellular wireless networks are an integral part of modern telecommunication systems. With the rapid growth of the number of cellular users and the scarcity of frequency spectrum, conventional cellular networks (CCNs) are facing difficulty in providing satisfactory service to users. To overcome the limitations of CCNs, an emerging architecture called the multihop cellular network (MCN) has gained a lot of attention. MCNs are emerging as a promising technology, benefiting from cellular and ad hoc network technologies. Multihop capability can be achieved in cellular networks by using relay nodes (RNs). For maximizing the benefit of multihop relaying, a good medium access control (MAC) layer scheme is required. In this work as a MAC scheme is proposed to meet the requirements of voice and World Wide Web (WWW) traffic in a multihop cellular network. In the proposed MAC scheme, the two classes of users (voice and WWW) contend with each other for resources based on class dependent permission probabilities. Fixed relaying technology is considered for multihop cellular networks. The performance of MCNs with voice traffic is quantified in terms of throughput, capacity, packet drop probability, power outage probability and packet interference probability. Two additional performance metrics are considered for WWW traffic: The average access delay per packet call and the average WWW packet transmission delay. The performance of the proposed MAC scheme in a multicellular system has been studied and compared with that of CCNs. The results indicate that MCNs with the proposed MAC scheme perform better than CCNs.

INDEX TERMS: CCNs, multihop, spectrum, MAC, relay nodes.

INTRODUCTION

There are different paradigms of wireless networks, with each targeting a different mode of connectivity and usage. Despite the differences, all wireless networks share some common properties and challenges. All wireless networks suffer from dealing with limited resources. The wireless medium is quite unreliable, has a relatively low bandwidth and is of broadcast nature. The radio spectrum is limited and there are channel impairments. But it is the wireless medium alone that supports mobility of users. All wireless transmissions share the same medium, that is, air. Therefore, the wireless networks should be designed to exhibit a high spectral efficiency and combat channel impairments such as multipath fading, shadowing and path loss for an enhanced homogeneous coverage. Wireless networks are built around a number of nodes which communicate with each other over a wireless channel. The provision of high capacity and reliable wireless multimedia communications to carry bursty packet

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traffic as well as voice and delay constrained traffic continues to be a challenging aspect of modern and future wireless communications networks.

On the basis of architecture, the wireless networks are divided into two groups: infrastructure based and infrastructure less. The networks with infrastructure include fixed and mobile terminal points. These networks include Conventional Cellular Networks (CCNs) [1], Local Wireless Networks (WLAN) [2], GSM [3] etc. In infrastructure based wireless cellular networks mobile terminals communicate directly with their base station and the base station establishes global connectivity through the infrastructure network. A network without infrastructure like mobile ad hoc network [4] [5] only contain mobile terminals (MTs) and it has no fixed station or wired connections. Each MT act as a host, as well as a router. MTs are randomly distributed in a given geographic area. MTs send packets to others or forward packets to reach the destination nodes in multiple hops. There are many advantages of these networks such as low cost and easy and fast deployment. However, such networks pose many challenges due to lack of infrastructure and the need for decentralized control and dynamic topology. Such networks do not scale very well and hence their application is limited to very specialized areas like rescue operations, battle fields and traveling groups. It is very difficult to provide uninterrupted high bandwidth connectivity to a large number of users with these network signals of different devices to be distinguished from each other. In general CDMA utilizes the available bandwidth better than either FDMA or TDMA in common situations. Implementation of CDMA is more complex, which is the primary reason why it was not generally adopted for the second generation. The use of CDMA requires a fundamental change in cellular network planning and deployment strategies, largely resulting from the fact that it enables a frequency reuse factor of 1 to be used. This can achieve high spectral efficiency but necessitates careful control of inter-cell interference [6]. Unlike the second generation circuit-switched networks, third generation (3G) networks have moved towards packet switching. The third generation technologies include UMTS (Universal Mobile Telecommunications System) and CDMA2000. The 3G mobile communication systems aim to provide enhanced voice, text and data services to the user. All of the 3G networks that have been deployed rely on CDMA for multiple access. Although referred to as generations, the technologies inside each generation are not as static as the terminology would employ. Already in the second generation GSM, there have been technologies called 2.5th G and 2.75th G. Such designations are intended to convey that they are a significant step forward in characteristics like bandwidth or latency but still compatible with the baseline technology. The 2.5th generation technology is called GPRS for General Packet Radio Service. GSM is circuit-switched, so GPRS was designed to offer packet-switched connectivity without requiring massive changes in the infrastructure. A further development EDGE, for Enhanced Data rates for GSM Evolution is referred to as 2.75th G. Similarly UMTS has spawned a 3.5th generation, a technology called HSPA (High speed Packet Access). 3G cellular systems are identified as International Mobile Telecommunications-2000 under International Telecommunication Union and as Universal Mobile Telecommunications Systems (UMTS) by European

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Telecommunications Standards Institute. Besides voice capability in 2G, the new 3G systems are required to have additional support on a variety of data-rate services using multiple access techniques [7]

The radio frequency bandwidth used for mobile communications has become a scarce and expensive medium as the number of mobile users increased to a greater extent and there is a huge demand of high data rate applications. Given the limitation on the spectrum, many researchers have attempted to increase the amount of data we can send with complex receiver structures, modulation schemes, and error correction and so on. Probably the greatest single advance in bandwidth utilization is the cellular concept. This means that bandwidth can be reused. With the rapid growth of the number of cellular users, and the scarcity of frequency spectrum, conventional cellular networks are facing difficulty in providing satisfactory signal to noise ratio (SNR) to users, especially to those at the cell boundary. One solution to support the increasing number of subscribers/users per cell is to decrease the cell radius/size. This result in a greater number of base stations required per area thus escalating the infrastructure costs. Also, smaller cell radius causes higher inter-cell interference which requires better frequency planning techniques to minimize interference. An alternate solution is to deploy low-cost relay nodes (RNs) in each cell to improve the system capacity and coverage area. A relay node is a node which assists in the transmission of data between other nodes in the network. Use of fixed relay nodes in a geographical area (which may or may not be covered by a base station or access point) can enable traffic forwarding in case of congestion and base station failures [109]. Relay-assisted multi-hop networks are expected to play a significant role in 4G wireless communication systems, because of its potential to cost effectively extend the coverage and/or increase the spectral efficiency. Relay-assisted cellular networks are called multihop cellular networks (MCNs). Multihop cellular networks [8] are designed based on the idea of using mobile and/or fixed terminals to relay signals from source nodes to BSs or destination nodes. In such architecture, the link is broken down into shorter paths requiring less power and hence creates less interference to the neighboring cell. With less interference, more users can be accepted in the system. Relaying enhances coverage, capacity and design flexibility with low cost.

We refer to the access methods used for these networks as random access methods accommodating randomly arriving packets of data. Certain local area data networks also take turns in accessing the medium as in the case of token passing and polling schemes. In some other cases, the random access mechanisms are used to temporarily reserve the medium for transmitting the packet. In other words, medium access using fixed assignment methods are efficient for a steady flow of data traffic; however, for intermittent or bursty traffic, these dedicated channels will be a waste of resources during the absence of data. The packet radio access to the medium is suitable for bursty traffic and competes for the access either randomly or in some coordinated way. A random access scheme provides a flexible and efficient way to manage the channel for bursts of messages at any time. In this scheme, the subscriber uses a contention

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technique to transmit the data packet to a common channel and senses the acknowledgement to ensure successful transmission. The choice of an access method will have a great impact on the capacity and QoS provided by a network. The impact of multiple access schemes is so important that we commonly refer to various voice-oriented wireless systems by their channel access method. A network that is identified with an access technique often uses other random or fixed assignment techniques as a part of its overall operation [9]Because all CDMA users appear as interference to other users, any excessive transmission power will increase the overall interference, which results in reduced capacity for the system. One way of controlling interference in CDMA networks is through power control to decide the transmission power so that signals reach intended receivers with predefined power. The importance of power control algorithms can be deduced from the situation when two MTs are transmitting to the same BS at the same time. If one MT is very close to the BS while the other is at the cell border, the signal of the MT close to the BS can overshadow the other MT's signal. Power control is essential in this situation so that the two signals reach the BS with comparable power (preferably equal). In this case, the two signals have the same interference effect on each other. By power control we mean the algorithms, protocols and techniques that are employed in a wireless network to dynamically adjust the transmit power of either the MT or BS for reducing interference. When power control is implemented properly, it can improve the quality of communications by increasing the SIR (Signal-to-Interference Ratio). Co-channel and adjacent channel interference are not the major problems in CDMA cellular networks. Instead the interference is from other users transmitting in the same frequency band at the same time. In order to avoid the near-far effect, it is important to implement good power control. Also in order to maintain a good link quality, effects such as fading and shadowing need to be countered by increasing the transmit power. Two types of power control are implemented- an open loop and a closed loop [10].

LITERATURE REVIEW

The rapid growth of wireless traffic has strengthened the demand for mobile communication networks with higher capacity, lower power consumption and greater coverage. Fourth generation wireless networks promise to meet these criteria while providing rich and diverse multimedia content requiring very high data rates. Cellular networks have evolved drastically from the 1st generation antilog cellular networks of the early 1980's which used primarily FDMA, to the 2nd generation digital cellular networks of the 1990's which used TDMA and CDMA to the 3rd generation cellular networks in use today which use wideband CDMA for multiple access. One aspect that has not changed is the core architecture of the cellular network where a mobile terminal is required to transmit directly to a base station to have its traffic sent onto the backbone network towards its ultimate destination. The traditional cellular network architecture may not have the flexibility to meet the requirements promised for 4G networks for the two following reasons. Firstly, fourth generation wireless networks promise to support transmission rates that are two orders of magnitude higher than those of 3G networks.

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The requirement of higher transmission rates is problematic because there is an inverse linear relationship between the transmission rate and the bit energy for a given transmission power level. The spectrum allocated to 4G networks in many countries is above the 2 GHz band that is used in 3G networks. Higher carrier frequencies have less favourable radio propagation characteristics because they are more vulnerable to non-line-of-sight conditions which are common in urban cellular communication.

A potential solution to these problems would be to increase the density of base stations thus reducing the size of each cell and increasing the supported data rate of mobile terminals. However, this solution is disadvantageous because the deployment cost of base stations is very high and customers are unlikely to be willing to pay the same cost per bit for data traffic as they have been paying for voice. From this discussion it becomes clear that major modifications to the traditional cellular architecture are necessary in order to meet these requirements for future wireless networks. For this reason, an emerging architecture called the multihop cellular network has gained a lot of attention from researchers as a potential candidate for future generation wireless networks. Several researchers have shown that we can increase the coverage and/or capacity of a wireless communication system, without adding more expensive network equipment by means of a technique called Multihopping. A wireless multi-hop network can be considered as a collection of dynamic wireless nodes that are located randomly and form a network with a routing structure in an ad hoc fashion [5]. Any kind of wireless network using relay nodes (RNs) can be referred to as multihop or wireless relay networks. In multihop networks, information from a source is relayed to a destination over multiple hops. Specifically, a direct transmission between the source and destination is replaced by multiple short transmissions over which data generated by the source is relayed. Multihop wireless networking traditionally has been studied in the context of ad hoc and peer-to-peer networks. If relaying is used in a cellular network, then such a network is referred to as multihop cellular network (MCN). The architecture of Multi-hop Cellular Network (MCN) was originally defined by Lin and Hsu [11]. MCNs combine the benefits of infrastructure based Conventional Cellular Networks (CCNs) and multihop Ad hoc networks. When the features of mobile ad hoc networks are combined with that of conventional infrastructure-based cellular networks, the multi-hop cellular wireless network is formed. In other words, the system becomes an enhanced cellular system with alternative relaying capability to communicate with the base station [12]. Mobile terminals can benefit from the alternative multi-hop path; this could provide greater throughput or better quality of service (QoS). Similarly, replacing long range high-power transmissions with several short range low-power relay transmissions could reduce energy consumption to the mobile terminals.

The architecture of MCN resembles that of CCN except that the transmission range of BSs and MTs is reduced. Hence the BS and MTs are not always mutually reachable in a single hop. Similar to ad-hoc networks, a key feature of MCN is that MTs can directly communicate with each other if they are mutually reachable, which is not allowed in CCN. This feature leads to multihopping. Signals of mobile nodes are relayed through a

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relaying device to a gateway device. Signals are then sent through a network controller (a mobile switching center (MSC), a radio network controller with a core network, or a router) to the public switching telephone networks (PSTN), the Internet, or other networks. A gateway device is typically a cellular BS. A relaying device can be a stationary dedicated repeater, wireless router, or MT. If MTs are used for relaying, the MCNs are basically a hybrid of cellular networks and ad hoc networks. Having hybrid network architecture, MCNs gain the benefits and inherit the weaknesses of both cellular networks and ad hoc networks [13]. In general, the wireless technology for MCNs is not limited to the cellular technology, such as second generation (2G) or 3G, but extends to infrastructure-based wireless networks such as WLANs and WiMAX.

MATERIALS AND METHODS

The wireless medium is a broadcast medium and therefore multiple devices can access the medium at the same time. For any wireless service, only a fixed limited finite amount of radio spectrum (or number of channels) is available to provide simultaneous communication links to many subscribers in a given service area. Thus, multiple simultaneous transmissions can result in garbled data, making communication impossible. The Medium Access Control (MAC) sub-layer is located in the lower Data Link layer, which is layer 2 in the ISO/OSI reference model. Functions of the MAC layer can be divided into following three groups: multiple access, resource sharing strategy (MAC protocol), and traffic control functions. The multiple access schemes establish a method of dividing the transmission resources into accessible sections that can be used by the network station to transfer various types of information. The task of a MAC protocol is the organization of a simultaneous access of the multiple network stations to the accessible sections of the network transmission resources provided by the multiple access schemes. Traffic control functions such as dynamic duplex mode, traffic scheduling and connection admission control are additional features of MAC layer and protocols. The basic function of the medium access control is to arrange packet transmission fairly and efficiently among multiple stations that share the same channel. In other words, the primary goal of MAC is to coordinate the channel access among multiple nodes to achieve high channel utilization. The coordination of channel access should minimize or eliminate the incidence of collisions and maximize spatial reuse at the same time [14] Medium access control is closely related to the condition of the physical channel. In wired networks, data is transmitted through the copper wires or fiber optics. Comparing to the wireless medium, the wired channel is much more reliable and provides abundant bandwidth. Packet error in the wired network is mostly caused by collisions. Therefore the MAC protocols for wired networks are relatively simple [15]. Unleashed from the restrictions of the messy cables, wireless communication offers great mobility by allowing the users to get access to the networks anytime, anywhere; meanwhile the freedom comes with a price. The often-fading and time-varying wireless links make the medium access control far more complicated than in the wired networks, presenting unexpected challenges to the protocol designers. The combination of network architecture, communication model, and duplexing mechanism define the

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general framework within which a MAC protocol is realized. Decisions made here will define how the entire system operates and the level of interaction between individual nodes. They will also limit what services can be offered and delineate MAC protocol design. However, the unique characteristics of wireless communication must also be taken into consideration [16] In CDMA, each active mobile subscriber is a source of noise to the receiver of other active mobile subscribers. If the number of active mobile subscribers is increased beyond a certain number in the system, the whole CDMA system collapses because the signal received in each specific mobile receiver will be buried under the noise caused by many other mobile subscribers. The main concern in a CDMA system is how many active mobile subscribers can simultaneously use it before the system collapses. A CDMA system is based on spread-spectrum technology by spreading the bandwidth of modulated signal substantially, which makes it less susceptible to the noise and interference. It is quite apparent that using a wider bandwidth for a single communication channel may be regarded as disadvantageous in terms of effective utilization of available spectrum. The received signals at the base station from a distant mobile subscriber could be masked by signals from a close mobile subscriber in the reverse (uplink) channel due to the near-far problem. However, by using power control that adjust the mobile transmitting power, enables to overcome the near-far problem and achieve high efficiency of frequency utilization in a CDMA system. CDMA has demonstrated an increase in system capacity compared with the analog and TDMA systems. This has resulted in CDMA becoming the popular choice for 3G systems. Although CDMA does provide an inherent flexibility for multimedia traffic, its disadvantage lies in the necessity for power control and implementation complexity. Co-channel and adjacent channel interference are not the major problems in CDMA systems. Instead the interference is from other users transmitting in the same frequency band at the same time. In order to maintain a good link quality, effects such as fading and shadowing need to be countered by increasing the transmit power.

RESULT AND DISCUSSION

A relay node breaks up a direct path for communication into two indirect paths. Placing a relay node within the cell raises new questions, such as where to place the relay node or how many relay nodes are required. In particular we are interested in determining optimal relay position which maximizes the overall performance.

In this work we have analyzed the performance of MCNs using the proposed MAC by varying the position of relay nodes in the cell. The cell radius is set to a constant value of 1.0 km (1000m) and the number of simultaneous users supported per cell is varied from 30 to 70. Six relay nodes are used. We have varied the position of relay nodes in cell from 0.3*cell radius to 0.7*cell radius. The results of various relay positions are compared with that of CCNs where no relay nodes are used.we find that the throughput of MCN is better when relay nodes are placed in the middle (0.4*R or 0.5*R) of the cell.

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From figure 1 we find that when RNs are placed near the center of the cell (close to the base station), the capacity of MCNs is less. When RNs are placed in the middle of the cell or near cell boundary MCNs have higher capacity.

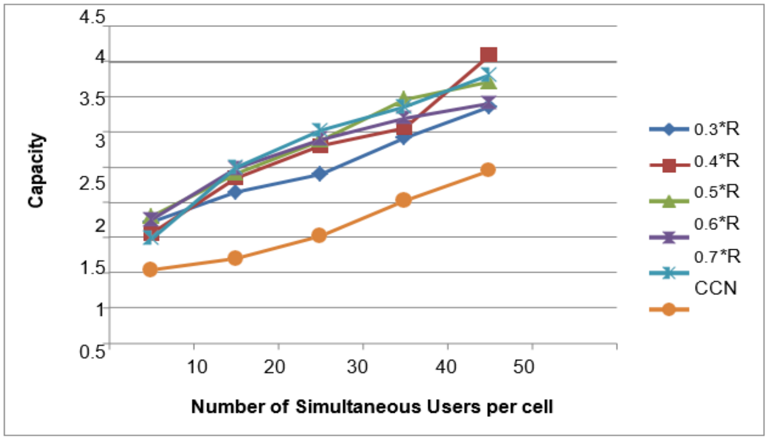
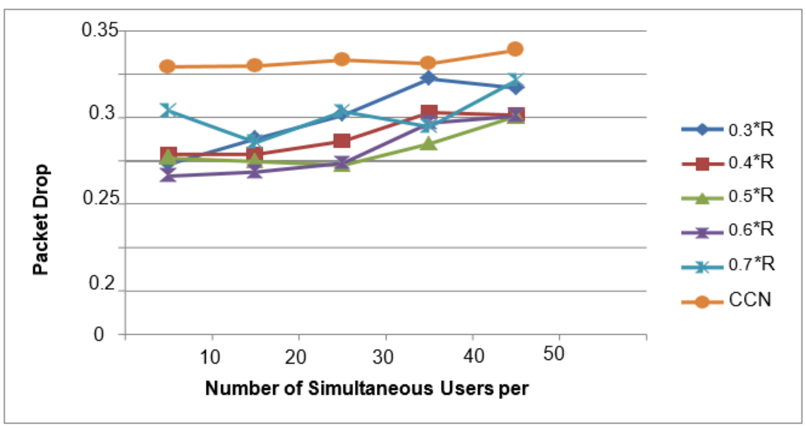


Figure: 1 Throughputs for various Relay Positions in MCNs and CCNs

From figure 2, we find that packet drop probability of MCNs is lower when RNs are placed in the middle positions in the cell.



From figure 3, it is clear that power outage probability of MCNs is lower when RNs are placed near cell boundary. For MTs near the base station, the required transmit power is low.

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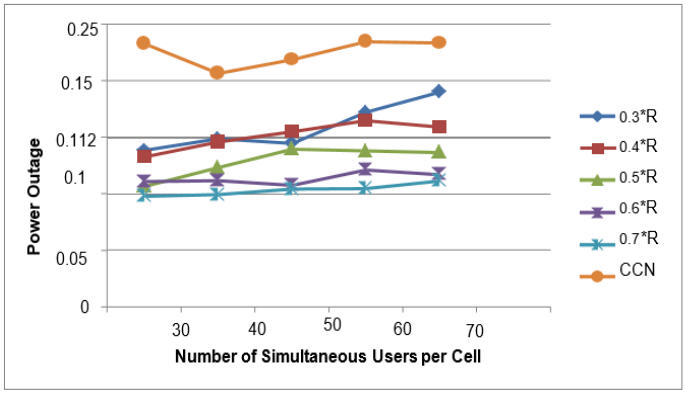
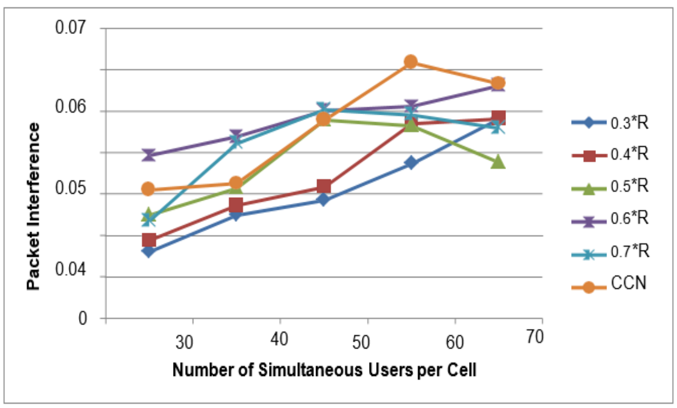


For MTs near the cell boundary, the required transmit power is high. Hence by placing relay nodes near the cell boundary, MTs near the cell boundary can relay their packets through RNs with less transmit power and hence the power outage probability becomes low.

It is clear from figure 4 that when relay nodes are placed near the middle of the cell, the packet interference probability is always lower than that of CCNs.



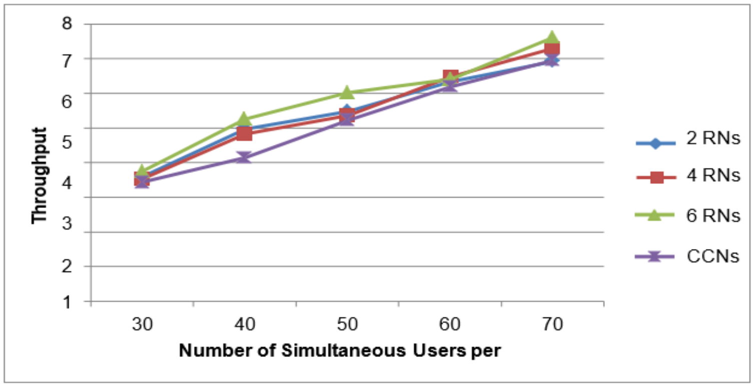
Packet Interference Probabilities for various Relay Positions in MCNs and CCNs

From figures 1 to 4, we find that whatever be the position of relay nodes in the cell, the performance is always better than that of CCNs.

Impact of Number of Relay Nodes on MAC Performance of MCNs and CCNs

For studying the impact of number of RNs on MAC performance of MCNs, the cell radius is set to a constant value of 1.0 km (1000 m) and the number of simultaneous users supported per cell is varied from 30 to 70. The position of relay nodes in cell is set to 0.4*R. We have varied number of RNs from 0 (CCNs) to 6. In particular, the MAC scheme deploying different number of relay nodes is compared in performance to a CCN where relaying is not used.

From figure 5, we find that, when more RNs are used the throughput is better because more MTs have paths to reach the BS.



From figure 6, we find that, when the number of simultaneous users per cell is low, increasing the number of RNs has not much effect on capacity. However, when the number of simultaneous users per cell is high increasing the number of RNs can increase the capacity considerably.

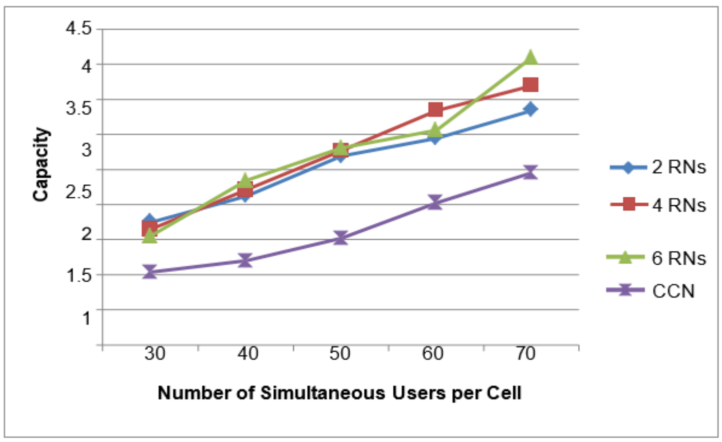


Figure 6.7 Capacities for various no. of RNs in MCNs and CCNs

From figure 7, it is clear that, for larger number of RNs, the packet drop probability is low because MTs will not have to wait for getting a relay node for packet transmission and hence the packets will have to be kept in the buffer for less time. Therefore fewer packets will be dropped.

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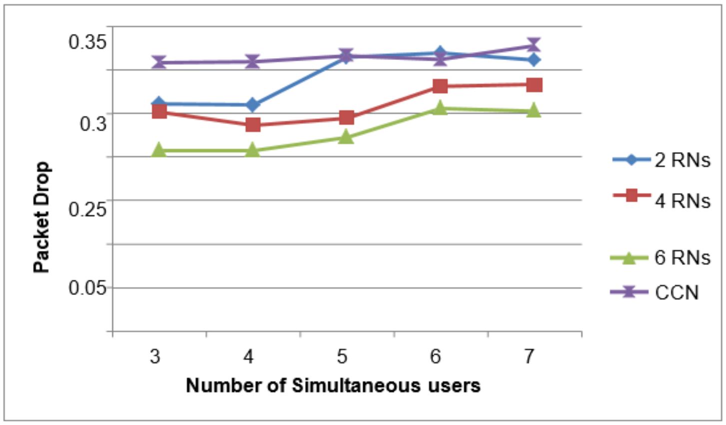
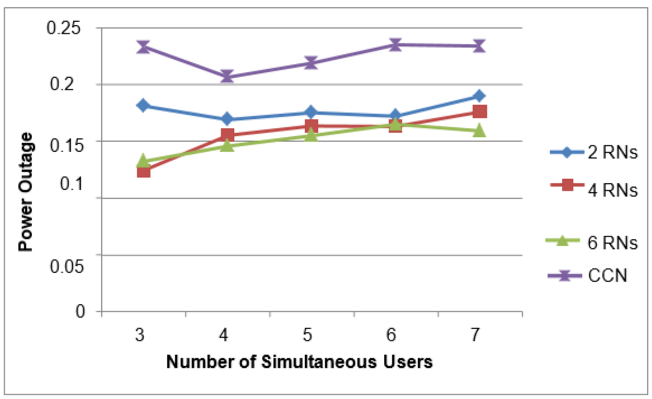
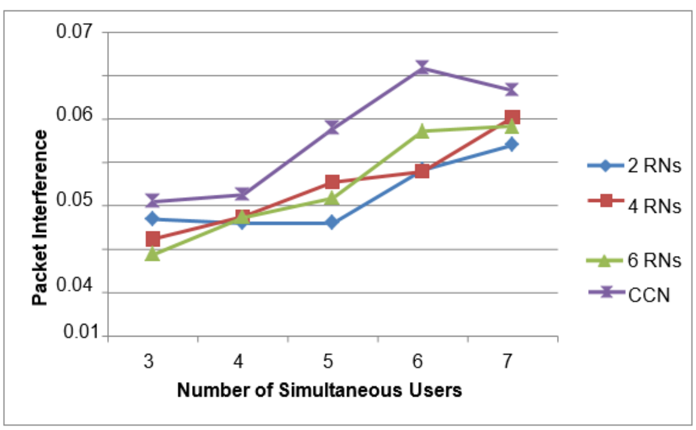


From figure 8, we find that for larger number of RNs, the power outage probability is lower than for less number of RNs.



If the number of RNs is large, most of the MTs will be able to find a RN and transmit their packets with lower power.

Figure 9 shows that the packet interference probability in CCNs is greater than MCNs.



From figures 6 to 9, it is clear that the when relay nodes are used, the performance is better than CCNs (no relay node). This is because if relay nodes are used, the transmission distance is reduced and less power is required to transmit packets in MCNs. we have investigated the performance of MCNs using the proposed MAC scheme for a number of system variables, including cell radius, transmit power levels, relay node locations, number of relay nodes, number of users etc. The results show that, for same values of parameters, MCNs perform better than CCNs in most of the cases. MCNs perform better than CCNs because they can reduce the transmission distance. Although MCNs can provide performance gains in most cases, one still needs to choose system parameters carefully for achieving maximum performance gains. With proper selection of different system parameters the performance of MCNs can be optimized.

CONCLUSIONS

Significant research has been done in the area of MAC protocols for various types of networks and architectures. MCNs combine the features of CCNs and ad hoc networks but MAC protocols for CCNs and ad hoc networks cannot be used directly for MCNs. Power control in cellular networks is another important design task. Many solutions to power control in CDMA systems have been proposed in the literature. But, they have focused on conventional cellular networks. From literature survey, it is concluded that average transmission power along with interference levels at relaying MTs (RNs), can be used for developing efficient power control scheme for multi-hop CDMA cellular networks. In this exploration a medium access control scheme is proposed to meet the requirements of voice and WWW traffic in a multihop cellular network. We have considered the case of an interference-limited cellular network by considering the effects such as shadowing, interference and path loss which provides a more realistic scenario of cellular environment. For implementation of the proposed MAC scheme, a simulator is designed for flexible representation of different aspects of MCN. The simulator is written in C++. The performance of the MAC scheme in a multicellular system has been studied and compared with that of conventional cellular networks. Fixed relaying technology is considered for multihop cellular networks. Two Power Control Schemes (based on SIR (Signal-to-interference ratio) and received power level) for MCNs are also implemented. The power control schemes require information which is feedback from the BS in the downlink. We also evaluated the performance of these two power control schemes. The results indicate that MCNs using the proposed MAC scheme and SIR based power control perform better than MCNs using received power level based power control.

References

1. E. Brand and A. H. Aghvami, —Multidimensional PRMA with prioritized Bayesian broadcast—a MAC strategy for multiservice traffic over UMTS," IEEE Transactions on Vehicular Technology, Vol. 47, November 1998, pp. 1148-1161.

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2. E. Brand, A. Hamid Aghvami, ―Performance of the Joint CDMA/PRMA Protocol for Voice Transmission in a Cellular Environment‖, in proceedings of IEEE International Conference on Converging Technologies of Tomorrow's Applications, Dallas, 1996, pp. 621-625.
3. Aasheesh Shukla, Dheeraj purwar, Dileep kumar, ―Multiple Access Scheme for Future (4G) Communication: A Comparison Survey‖, International Symposium on Devices MEMS, Intelligent Systems & Communication (ISDMISC) Proceedings published by International Journal of Computer Applications (IJCA), 2011, pp.1-4.
4. Abbas Jamalipour, Tadahiro Wada, Takaya Yamazato, ―A Tutorial on Multiple Access Technologies for Beyond 3G Mobile Networks‖, IEEE Communications Magazine, February 2005, pp. 110-117.
5. Ali NabiZadeh, BijanJabbari, ―On the Capacity Modeling of Multihop Cellular Packet CDMA Networks‖, in proceedings of IEEE Military Communications Conference, 2001, pp. 600-604.
6. Ali, R.B., Hafid, A., Rezgui, J., ―An Enhanced Reservation-Based Medium Access Control with Scheduling and Admission Control for Voice over Wireless Mesh Networks‖, in proceedings of IEEE Global Telecommunications Conference, Miami, 2010, pp. 1-6.
7. Amjad Umar, ―Mobile Computing and Wireless Communications‖, Chapter 5, NGE Solutions, 2004, pp. 44-46, ISBN 0-9759182-0-6.
8. Amr El-Sherif, Andres Kwasinski, Ahmed K. Sadek, and K. J. Ray Liu, ―Content-Aware Multiple Access Protocol for Cooperative Packet Speech Communications‖, IEEE Transactions on Wireless Communications, Vol. 8, No. 2, February 2009, pp. 995-1005.
9. Ananthapadmanabha R., B. S. Manoj and C. Siva Ram Murthy, ―Multi-hop Cellular Networks: The Architecture and Routing Protocols‖, in proceedings of IEEE PIMRC, San Diego October 2001, pp. 78-82.
10. Aravind Iyer, Catherine Rosenberg, "Understanding the Key Performance Issues with MAC Protocols for Multihop Wireless Networks", wireless Communications and Mobile Computing, 2006, pp.745-760.
11. Ayman Radwan, Hossam S. Hassanein, ―Multi-hop CDMA Cellular Networks with Power Control‖, in proceedings of IWCMC'06, Vancouver, British Columbia, Canada, July 3–6, 2006, pp. 325-330. REFERENCES 154
12. Bhargava, X. Wu, Y. Lu, W. Wang, ―Integrating heterogeneous wireless technologies: a cellular aided mobile ad hoc network (CAMA)‖, Mobile Networks and Applications 9 (2004) 393–408.
13. Behzad Kasiri, Hadi Meshgi, Majid Naderi and Bahman Abolhassani, ―Diversity-Based Relay Selection for Multihop Cellular Networks‖, in proceedings of IEEE International Conference on Advanced Computer Theory and Engineering, Phuket, 2008, pp. 740-743.
14. Benyuan Liu, Patrick Thiran, Don Towsley, ―Capacity of a Wireless Ad Hoc Network with Infrastructure‖, in proceedings of ACM international symposium on MobiHoc'07, September 9–14, Canada, 2007, pp. 239-246.
15. Siva Ram Murthy and B. S. Manoj: "Ad Hoc Wireless Networks: Architectures and Protocols", Prentice Hall, ISBN 9780131470231.
16. Y. Kao and J. Mar, ―Intelligent MBWIMA/UMTS protocol using cascade fuzzy logic control for UTRA TDD mode," IEEE Transactions on Vehicular Technoliogy, Vol. 52, November 2003, pp. 1663-1674.
17. Deborah A. Dyson and Zygmunt J. Haas, ―A Dynamic Packet Reservation Multiple Access Scheme for Wireless ATM‖, in proceedings of MILCOM, Monterey, November 1997, pp. 687- 693.

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18. DeFaria M., Sousa E.S., ―Effect of intercell interference on the SNIR of a multihop cellular network‖, in proceedings of IEEE Vehicular Technology Conference, June 2005, pp. 3107- 3111.

19. Dhananjay Kumar, Chellappan C, ―Adaptive Call Admission Control in TDD-CDMA Cellular Wireless Networks‖, UbiCC Journal, Volume 4, Number 3, August 2009, pp.834-840.

20. Kudoh, F. Adachi, ―Power and frequency efficient wireless multihop virtual cellular concept‖, IEICE Transactions on Communications E88B (4), 2005, pp. 1613–1621.

21. FengShu, Taka Sakurai, Moshe Zukerman, Mansoor Shafi, ―A Joint PRMA and Packet Scheduling MAC Protocol for Multimedia CDMA Cellular Networks‖, in proceedings of IEEE 16th International Symposium on Personal, Indoor and Mobile Radio Communications, Berlin, September 2005, pp. 2216-2220.

22. Giuseppe Bianchi, Flaminio Borgonovo, Luigi Fratta, Luigi Musumeci, and Michele Zorzi, Member, IEEE, "C-PRMA: A Centralized Packet Reservation Multiple Access for Local Wireless Communications‖, IEEE Transactions on Vehicular Technology, Vol. 46, No. 2, May 1997, pp. 422-436.

23. Gunnar Heine, ―GSM Networks: Protocols, Terminology and Implementation‖, Artech House, London, 1999, pp. 1-10. REFERENCES 155

24. H. Li, D. Yu, H. Chen, ―New approach to multihop—cellular based multihop network‖, in proceedings of IEEE PIMRC'03, Beijing, China, 7–10 September 2003, pp. 1629–1633.

25. H. Li, M. Lott, M. Weckerle, W. Zirwas, E. Schulz, ―Multihop Communications in Future Mobile Radio Networks‖, in proceedings of IEEE PIMRC, September 2002, pp. 54-58.

26. H. Luo, R. Ramjee, P. Sinha, L.E. Li, S. Lu, ―UCAN: a unified cellular and ad-hoc network architecture‖, in proceedings of ACM MOBICOM'03, San Diego, CA, USA, 14–19 September 2003, pp. 353–367.

27. H. Nourizadeh, S. Nourizadeh, R. Tafazolli, ―Performance evaluation of Cellular Networks with Mobile and Fixed Relay Station‖,in proceedings of IEEE Vehicular Technology Conference,Montreal, September 2006, pp. 1-5.