COMPARATIVE STUDY OF NEXT GENERATION HIGH SPEED WIRELESS NETWORKS

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Abstract

Advances in mobile communication theory have enabled the development of different wireless access technologies. Alongside the revolutionary progress in wireless access technologies, advances in wireless access devices such as laptops, palmtops, and cell phones and mobile middleware have paved the way for the delivery of beyond-voice-type services while on the move. This sets the platform for high-speed mobile communications that provide high-speed data and both real and non-real time multimedia to mobile users. Today's wireless world uses several communication infrastructures such as Bluetooth for personal area, IEEE 802.11 for local area, Universal Mobile Telecommunication System (UMTS) for wide area, and Satellite networks for global networking other hand, since these wireless networks are complementary to each other, their integration and coordinated operation can provide ubiquitous “always best connection" quality mobile communications to the users. This paper discusses the different architectures of wireless networks and the different factors to be considered while designing a hybrid wireless network. The different factors to be considered for design of a hybrid wireless network and the different networks have been explored in this paper.

Keywords: Wireless Networks; Mobile Communication; Ad hoc networks; throughput, spectrum reusability; overlay, bandwidth.

1. Introduction

In wireless networks, mobile users use multi-mode terminals that are equipped with multiple air interfaces and adaptive protocols so that the same terminal can be used for different networks. Using these terminals, mobile users are always connected to the best available network or networks. When users move out of the coverage of the serving network, their terminals automatically switch to another network such that the applications do not experience connection interruption. Therefore, users perceive different wireless networks as a single integrated system. We refer to this integrated system as the next-generation wireless systems (NGWS).The next generation wireless networks face new challenges in the form of increasing volume of traffic with the increase in number of users and the average traffic generated by users.

2. Literature Review

In this paper, Chandra, A. et al. [1] discussed Wireless radio relays that are one of the possible contenders to extend the capacity and reliability of broadband data channels envisaged for 4G. Several research and standardization groups are engaged in evaluating and evolving the range of applications with radio relays. There are both pros and cons of this technology, which needs to be carefully addressed before its actual implementation. Its cost effectiveness will also be a deciding factor in a particular application scenario with respect to other competing technologies.

In this article Chen, C.T. et al. [2] proposed QoS constrained network lifetime extension cellular ad hoc augmented network (QCLE CAHAN) architecture for next generation wireless networks. The QCLE CAHAN architecture was proposed to achieve the maximum network lifetime under the end-to-end hop-count constraint

(QoS constraint). QCLE CAHAN is a hybrid architecture, in which each MT (mobile terminal) of CDMA cellular networks has ad hoc communication capability. They showed that the network lifetime is much higher in the case of QCLE CAHAN than in the case of traditional cellular networks.

Bhalla, M.R. et al. [10] lighted on the evolution and development of various generations of mobile wireless technology along with their significance and advantages of one over the other. In the past few decades, mobile wireless technologies have experience 4 or 5 generations of technology revolution and evolution, namely from 0G to 4G. Current research in mobile wireless technology concentrates on advance implementation of 4G technology and 5G technology. Currently 5G term is not officially used. In 5G researches are being made on development of World Wide Wireless Web (WWWW), dynamic Ad hoc Wireless Networks (DAWN) and Real Wireless World.

Sharma, V. et al. [13] reviewed a number of MCN-type architectures, concepts and issues in literature through a comprehensive discussion. This will help to explore new areas of future research in the field of multihop cellular network.

The traditional centralized load balancing had relatively low reliability, and the distributed load balancing has a huge overhead. To solve these problems, Shi, W. et al. [5] mapped heterogeneous wireless networks to distributed grids by introducing Resource Management Unit, and then presented a hierarchical semi-centralized architecture for load balancing of heterogeneous wireless networks drawing on the idea of grid in computer networks. The analytical models for the integrated reliability and signalling overhead of the architecture were established. Theoretical analysis and simulation results indicated that the architecture can reduce the signalling overhead and improve the system reliability effectively.

Law,L.K. et al. [9] defined the capacity of the hybrid network as the maximum possible downlink throughput under the constraint of max-min fairness. They analytically computed the capacity of both one and two dimensional hybrid networks with regular placement of base stations and users. While almost no capacity benefits are possible with linear networks due to poor spatial reuse, significant capacity improvements with two-dimensional networks were possible in certain parametric regimes. Their simulations also demonstrated that in both cases, if the users were placed randomly, the behavioural results were similar to those with regular placement of users.

Bajaj, P. et al. [14] discussed Next generation mobile networks that are commonly referred to as 4G, and are envisaged as a multitude of heterogeneous systems interacting through a horizontal IP-centric architecture.4G must be dynamic and adaptable with built-in intelligence. Key challenges will be personalization, seamless access, quality of service, intelligent billing. Future wireless networks will need to support diverse IP multimedia applications to allow sharing of resources among multiple users. There must be a low complexity of implementation and an efficient means of negotiation between the end users and the wireless infrastructure. In this paper they discussed challenges, Service & applications in next generation mobile network.

Luo, H. et al. [21] proposed the Unified Cellular and Ad Hoc Network (UCAN) architecture for enhancing cell throughput while maintaining fairness. In UCAN, a mobile client has both 3G interface and IEEE 802.11-based peer-to-peer links. The 3G base station forwards packets for destination clients with poor channel quality to proxy clients with better channel quality. The proxy clients then use an ad hoc network composed of other mobile clients and IEEE 802.11 wireless links to forward the packets to the appropriate destinations, thereby improving cell throughput. They refined the 3G base station scheduling algorithm so that the throughput gains are distributed in proportion to users' average channel rates, thereby maintaining fairness. They further proposed secure crediting mechanisms to motivate users that are not actively receiving to participate in relaying packets for others.

Kannan, G. et al. [20] proposed a CDMA-OFDM access mechanism for Multihop Cellular Networks (MCN). They constructed groups within the MCN, where each group comprises of a source node, a destination node, and their intermediate relay nodes and assign a correlated PN sequence to each such group. Within a particular group, a single carrier is assigned to each intermediate hop. The sub carriers assigned to the intermediate hops in a given group are mutually orthogonal. Hence the proposed OFDM is FDMA in nature. Simulation results showed that the proposed access mechanism achieves better end-to-end throughput and bit error rate (BER) performance as compared to standard access mechanisms like CDMA and OFDM-FDMA. Furthermore the proposed access mechanism has considerably higher BER performance in the presence of multiple transmit sources.

Hybrid wireless networks have emerged as a promising solution, allowing mobile clients to achieve higher performance and service access in a seamless manner independent of their existence in wireless LAN (WLAN) communication range. In this paper Tchepnda, C. et al. [22] addressed the benefits of hybrid wireless networks, showing their possible applications and presenting a classification for their emerging architectures. Also, they identified the research challenge arising from the problem of applying the grid computing concept in such hybrid wireless environment, showing the expected benefits from the aggregated fixed-mobile capacity. Finally, they proposed their vision for a potential architectural model, which was expected to provide useful services by the network operator or the service provider in such a hybrid environment.

Wu, H. et al. [25] proposed a novel architecture for next generation wireless systems called iCAR (integrated cellular and ad hoc relaying systems) which integrates the traditional cellular and modern relaying technologies. They evolved the performance improvement of iCAR over conventional cellular systems under Erlang-B traffic model. The basic idea of the iCAR was to place a number of ARSs in a cellular system to divert excess traffic from one (possibly congested) cell to another. They compared the performance of the iCAR system with the conventional cellular system via analysis and simulations in terms of the call blocking\dropping probability, throughput and signaling overhead in both the hot cell and overall subsystem.

The SOPRANO project involves a novel adaptive and scalable wireless network architecture utilizing a mixture of cellular and multihop packet radio system topologies with the potential to support a variety of applications including high-data rate Internet and multimedia traffic at a reasonable degree of implementation complexity. Zadeh, A.N. et al. [24] discussed the potential benefits of self organizing packet radio ad hoc networks with overlay (SOPRANO) structure and address several relevant issues necessary to support such a network. It focused on connection establishment and self organization, investigated the formulation of an optimum transmission strategy and examined the techniques by which the performance and capacity of the multihop network was increased. They further addressed some of the many new challenges which were encountered in optimizing the capacity of this structure. They saw several illustrations of how different combinations of such techniques yield a multihop increase in system capacity. With the feasibility of increasingly sophisticated wireless devices, multihop networking promises a widely spread network with high data rate support.

In mobile-assisted data forwarding (MADF) Wu, X. et al. [26] added an ad-hoc overlay to the fixed cellular infrastructure and special channels-called forwarding channels-were used to connect users in a hot and its surrounding cold cells without going through the hot cell's base station. The forwarding-channel management in MADF was done by the mobile units themselves to relieve the load on the CC. They found that, using MADF, under a certain delay requirement, the system performance can be greatly improved.

Luo, H. et al. [23] proposed the Unified Cellular and Ad-Hoc Network (UCAN) architecture for enhancing cell throughput, while maintaining fairness. They proposed novel greedy and on-demand protocols for proxy discovery and ad-hoc routing that explicitly leverage the existence of the 3G infrastructure to reduce complexity and improve reliability.

3. Hybrid Wireless Networks

Next generation hybrid wireless network architectures are known as Hybrid networks because they combine the benefits of ad hoc wireless networks and cellular networks. The principle behind Ad hoc networking is Mulithop relaying in which massages are sent from the source to destination by relaying through the intermediate hopes. Routing is done through intermediate nodes and\or base stations. Base stations are used for keeping routing information. Multihop relaying is used in this architecture. It is self-organized network. Every node looks for activities of its neighbour. Nodes exchange topology information periodically. It tries to find new paths on path breaks through routing protocols. These architectures can be divided on the basis of system with dedicated relay stations or on the systems host-cum relay stations. The next generation networks are expected to reuse the spectrum better. If we want to increase the throughput of traditional cellular networks, we use multi hop cellular network (MCN), integrated cellular and ad hoc relaying system (ICAR), hybrid wireless network (HWN) architecture, self organizing packet radio networks with overlay (SOPRANO), multi power architecture for cellular network (MuPAC) & throughput enhanced wireless in local loop (TwiLL). Examples of other hybrid architecture include mobile assisted data forwarding (MADF) system, ad hoc GSM (A-GSM), directional throughput enhanced wireless in local loop (DwiLL) and unified cellular and ad hoc network (UCAN). These architectures are used to reduce interference, extended coverage broadband support over extended range, increased reliability and support for large number of users.

3.1. The Mcn Architecture

Multihop Cellular Network (MCN) as a viable alternative to the conventional Single-hop Cellular Network (SCN) by combining the features of SCN and ad-hoc networks. In this connection between source and destination is established over a multihop path. In MCN, mobile stations help to relay packets, which are not allowed in other variant systems of SCN, such as Ricochet network and mobile base network. MCN has several merits viz. the number of bases or the transmission ranges of both mobile stations and base can be reduced, connections are still allowed without base stations, multiple packets can be simultaneously transmitted within a cell of the corresponding SCN, and paths are less vulnerable than the ones in adhoc networks because the bases can help to reduce the wireless hop count. MCN suggests that he transmission power of the MHs and the BS over the data channel(r) be reduced to a fraction 1/k (where k is reuse factor) of the cell radius R. This means that more than one node can transmit simultaneously on the same channel.

Duplexing Schemes used by MCNs

In MCN, relay stations transmit data to the base stations and receive data from the mobile stations. This affects self interference at the relay stations. To avoid the self interference at relay stations, the relay stations should not transmit and receive on the same frequency at the same time. Multihop transmission can be used in frequency division duplex or time division duplex.

Frequency division duplexing (FDD): FDD multihop cellular networks require two paired frequency channels. One paired frequency channel is for uplink and downlink transmission between MSs and RSs. The other paired frequency channel is for uplink and downlink transmission between MSs/RSs and BSs. In addition, each RS needs to have two antennas to separate the transmission and reception. Thus, multihop in FDD requires additional paired frequency channel and two antennas.

Time division duplexing (TDD): TDD multihop cellular networks require a single antenna in each relay station because transmission to BS and reception from MS at the RS can be separated by different time slot. One paired frequency channel is required to separate the transmission to BSs and reception from MSs at RSs because the transmission to BSs and reception from MSs at RSs is separated by different time slots.

3.2 The MADF Architecture

In mobile-assisted data forwarding (MADF), an ad-hoc overlay is added to the fixed cellular infrastructure and special channels called forwarding channels are used to connect mobile units in a hot cell and its surrounding cold cells without going through the hot cell’s base station. The main objective of this system is to divert the traffic load from hot cell to cooler cell in its neighbourhood to achieve load balancing. Figure 1 shows the operation of this architecture. The shaded cells describe the hot cells. User B, User D, and User G are forwarding agents .It takes two hops for the packet from User C to reach to the a base station. On the other hand, since User E cannot find an immediate forwarding agent in its neighbouring cold cell, it takes three hops for its data to reach to a base station. For the users out of the coverage of this wireless network (such as User H), they can accordingly forward their packets to an agent (such as User G) in order to stay connected to the network. Note that a forwarding agent may serve multiple users at the same time.

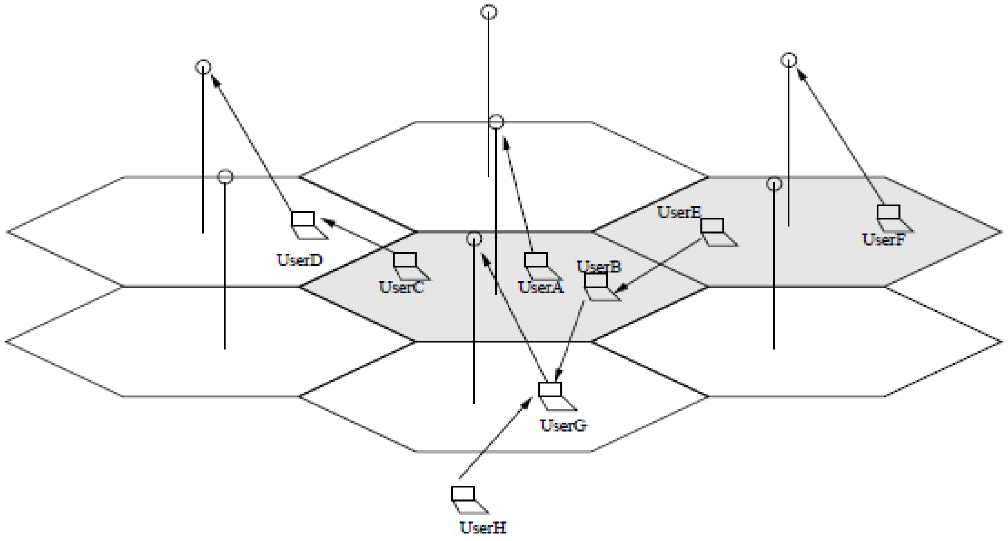

Figure 1 A wireless data network with MADF

In MADF, power control may be required in order to reduce the co-channel interference of the forwarding channel. This is illustrated for the case of Users B and C, in which User C and User B may use the same forwarding channel but may be near to each other. The forwarding channels can be “in-band,” in which the channels are allocated from the cellular channel pool. On the other hand, “out-of-band” forwarding channels are special channels (e.g., Bluetooth channels) not in the pool of the cellular channels.

3.3 The Icar Architecture

The integrated cellular and ad hoc relaying system (iCAR) is a next generation wireless architecture that can easily evolve from the cellular infrastructure. The iCAR uses a number of ad hoc relaying stations (ARS) placed at proper location to relay excess call traffic from hot cells to cool cells around it. There are three types of relaying methods in iCAR.

Primary Relaying: In an existing cellular system, if MH X make a new call but it is in a congested cell B, the new call will be blocked. In the proposed system with integrated cellular and relaying technologies, the call may not have to be blocked. More specifically, MH X which is in the congested cell B can switch over to the R interface to communicate with an ARS in cell A, possibly through other ARSs in cell B (see Fig. 2 for an example). This strategy is known as primary relaying. With primary relaying, MH X can communicate with BTS A through relaying. Hereafter, we will refer to the process of changing from the C interface to the R interface (or vice versa) as switching-over, which is similar to (but different from) frequency hopping. Of course, MH X may also be relayed to another nearby noncongested cell other than cell A. A relaying route between MH X and its corresponding (i.e., caller) MH X may also be established (in which case, both MHs need to switch over from their C interfaces to their R interfaces), even though the probability that this occurs is typically very low.

Secondary Relaying: If primary relaying is not possible, because, for example in Fig. 2, ARS 1 is not close enough to MH X to be a proxy (and there are no other nearby ARSs), then one may resort to secondary relaying so as to free up a DCH from BTS B for use by MH X. Two basic cases are illustrated in Fig. 3(a) and (b), respectively, where MH Y denotes any MH in cell B which is currently involved in a call. More specifically, as shown in Fig. 3(a), one may establish a relaying route between MH Y and BTS A (or any other cell). In this way, after MH Y switches over, the DCH used by MH Y can now be used by MH X. Similarly, as shown in Fig. 3(b), one may establish a relaying route between MH Y and its corresponding MH Y in cell B or in cell C, depending on whether MH Y is involved in an intracell call or an intercell call. Note that congestion in cell B implies that there are a lot of on-going calls (involving candidates like MH Y); hence, the likelihood of secondary relaying [refer to Fig. 3(a) and (b)] should be better than that of primary relaying (refer to Fig. 2).

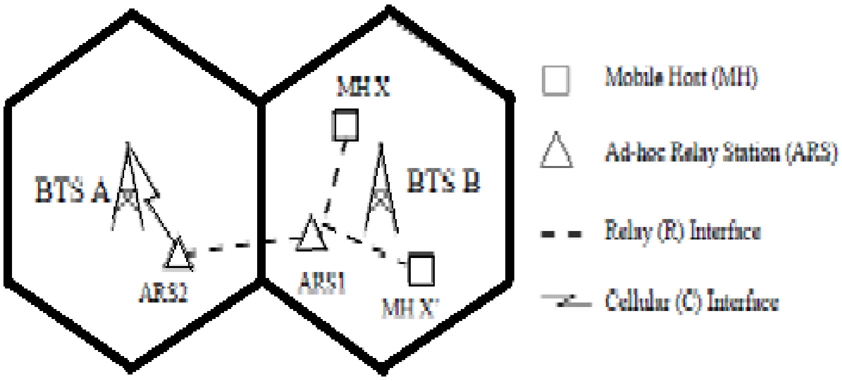

Figure 2. Primary relaying

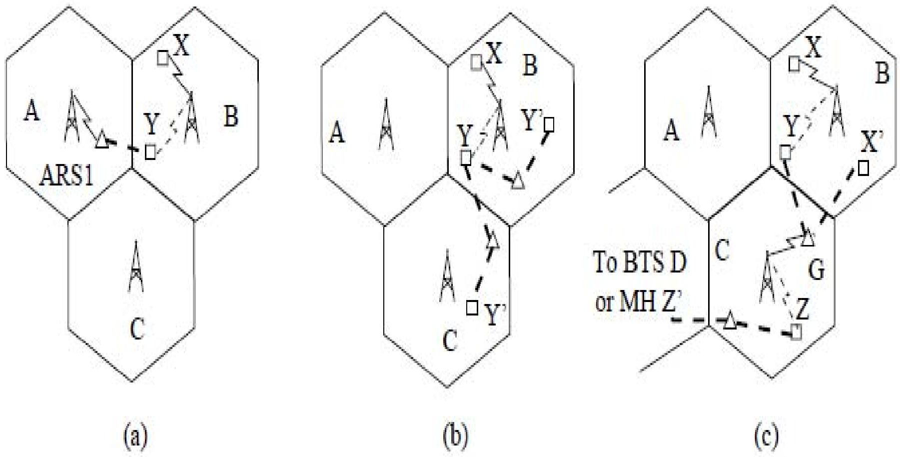

Figure 3 Secondary relaying to free up a channel for MH X. (a) MH Y to BTS A, (b) MH Y to MH Y', or (c) cascaded secondary relaying (i.e. MH Y to BTS C and MH Z to either MH Z' or BTS D).

Cascaded Relaying: If neither primary relaying, nor basic secondary relaying works, the new call may still be supported. More specifically, assume that there is a relaying route, which can be either primary or secondary relayed, between MH X and ARS, say G (for gateway), in a nearby cell C which unfortunately is congested. As shown in Fig. 3(c), one may apply any of the two basic secondary relaying strategies described above in the congested cell C (i.e., in a cascaded fashion) to establish a relaying route between an MH (say MH Z) in cell C and either another BTS in a non congested cell or MH Z . In this way, ARS G can be allocated the DCH previously used by MH Z in cell C, and, in turn, MH X can be allocated the DCH previously used by MH Y in cell B if the route between MH X and ARS G is set up by secondary relaying.

3.4 The Soprano Architecture

The self-organizing packet radio ad hoc network with overlay (SOPRANO) architecture is a wireless multihop network overlaid on a cellular structure. This is a slotted CDMA system which uses dedicated relay stations where a repeater forms a hexagon or a random shape as shown in figure 4. The repeaters do not generate traffic on their own; rather they help MHs to forward traffic.Neighbour discovery in SOPRANO architecture is done on powering up the MH by receiving the carrier signal from the nearest repeater.

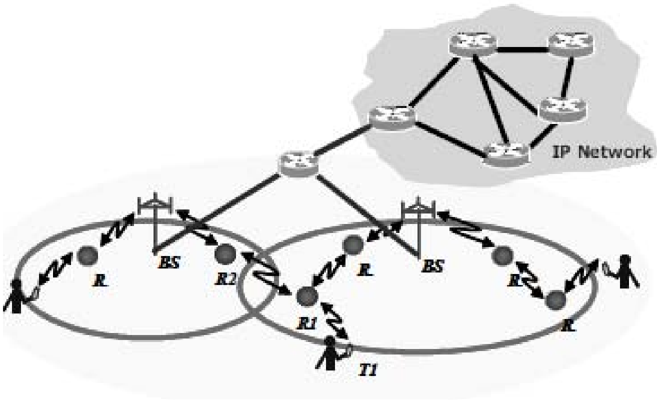

Figure 4.The SOPRANO Architecture

Every node updates its location by registration process. SOPRANO assumes the use of asynchronous CDMA with a large number of spreading sequences. A channel assignment process is used to inform every node about the channel to be used by that node. It provides high data rate. Two separate frequency bands are assumed to carry the information, one each for up-streams and down streams. The upstream and downstream transmissions in SOPRANO may involve multiple routers, and thus routers must be able to receive on all the channels on which they transmit. Also, note that due to the high power level difference between transmit and receive signals, simultaneous transmission and reception in the same frequency band is not practical. Thus, from an implementation point of view, the simplest practical way of creating transmit and receive channels is to use a time division duplex (TDD) scheme.

3.5 The Mupac Architecture

The multi-power architecture for cellular networks (MuPAC) is a multichannel architecture, where n-channel architecture has n+ 1 channel, each operating at a different transmission range. The available bandwidth is divided into a control channel (used for sending topology information and routing control packets) using a transmission range equal to the cell radius(R) and n data channel each operating at different transmission range as shown in figure 5 . Where channel 1 uses R/3 transmission range and channel 2 uses R/2 transmission range.

3.6 The Twill Architecture

A wireless multihop architecture based on MCN for local loops called Throughput enhanced Wireless in Local Loop (TWiLL). The bandwidth available is split into one control channel and several data channels which are not clustered between cells. One way to solve the problem of network partitions in a multihop system is to allocate a channel ch in single-hop mode, whenever the MH requesting call setup finds itself in partition i.e., there does not exist a multihop path to the BS. Following the above philosophy in TWiLL, every channel will be designated as a multihop channel (MC) or a single-hop channel (SC). An MH transmits in the control channel and SCs with a range of R (cell radius) and in the MCs with a range of $r = R/2$ thus keeping the reuse factor $k = 2$ among the MCs. The introduction of some single-hop channels into a multihop environment is done to keep the network connected in case a partition occurs. Let the number of MCs be Nm and the number of SCs be Ns. The call establishment process is similar to that in MCN.

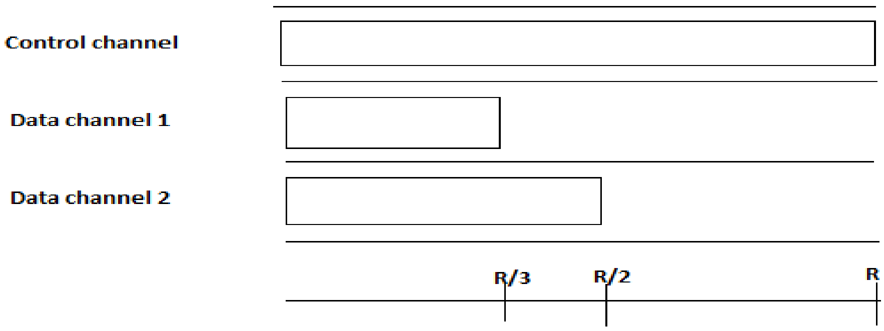

Figure 5 A two channel MuPAC network

To establish a call an MH sends a Route Request (RReq) to the BS over the control channel. The BS computes a multihop path and allocates MCs along the path from the MH to itself using the same method as in MCN. If such a path cannot be obtained, then the MH is given an SC to communicate directly with the BS. The allocation of channels in single-hop mode will reduce the spatial reuse of bandwidth thus reducing the network throughput, but will also increase the number of accepted calls when the node density is lesser than required, thus increasing the network throughput. When a call is requested to be setup,the probability that the calls' destination is within the same cell as the call's source is defined as the locality of the system. Locality does not affect the throughput of WLL since, irrespective of its value two channels will be setup. However in TWiLL, locality can be used to improve the throughput by a technique called Shortcut relaying.

3.7 The Dwill Architecture

Directional throughput-enhanced wireless in local loop (DWiLL) is high performance architecture for wireless in local loop systems. It employs a unique combination of directional multihop relaying in the uplink and single hop relaying in the downlink to reuse bandwidth and thus improve the throughput of WLL systems. The major advantages of DWiLL include reduction in the energy expenditure at the fixed subscriber unit and the ability to provide enhanced throughput when the number of subscribers become large. The system architecture is similar to the TWiLL architecture. The spectrum is divided into a number of channels. The difference between TWiLL and DWiLL is the use of directional relaying by the FSUs in DWiLL.

3.8 The Hwn Architecture

The hybrid wireless network architecture operates in two modes namely ad hoc mode and cellular mode. This architecture requires the global positioning system (GPS) because nodes need to know their exact geographical location. Figure 6(a) shows the operation of HWN in the cellular mode. In this mode the node sends its packet to its base B, which forwards it to the destination C. The transmission range of every node is R (the cell radius). The operation of ad hoc mode is shown in figure 6(b). In this mode, the node A uses the DSA (dynamic source routing) protocol to discover rout to the destination. It floods route request packets which reach the destination D after relayed by B and C. D now sends a route reply packet which reaches the node A, which then begins to sand packet along the newly discovered route. Here the path from A to D does not evolve the base at all. Neither the base is necessary for finding the route. The ad hoc mode is useful in dense topologies and the cellular mode is better for sparse topologies.

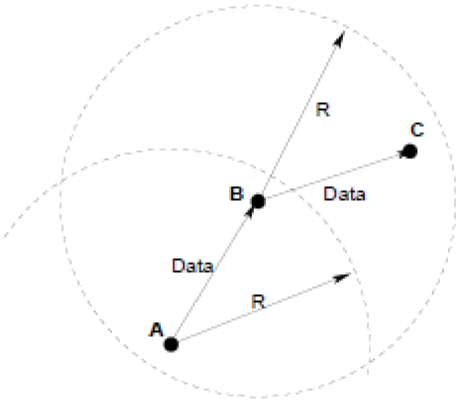

Figure 6(a) Hybrid Architecture in cellular mode

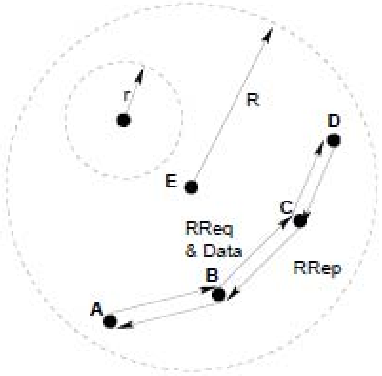

Figure 6(b) Hybrid Architecture in ad hoc mode

3.9 The Ucan Architecture

Unified cellular and ad hoc network architecture is a hybrid wireless network architecture that combines wireless WANs and 802.11b based ad hoc wireless networks. Every node requires multiple radio interfaces, narrow bandwidth, high transmission range interface to directly communicate to the BS and the high bandwidth, low transmission range interface for multihop communication. UCAN is a technology specific architecture, where the WAN part is a CDMA based 1xEVDO-HDR (1xEvolution Data Only High Data Rate) network and the ad hoc communication is based on IEEE 802.11b standard. In the UCAN model each mobile device is equipped with two wireless interfaces. Fortunately, given the popularity of the IEEE 802.11b (Wi-Fi) interface, it is already being embedded in every mobile device and thus the device only needs a 3G interface card to operate in UCAN.

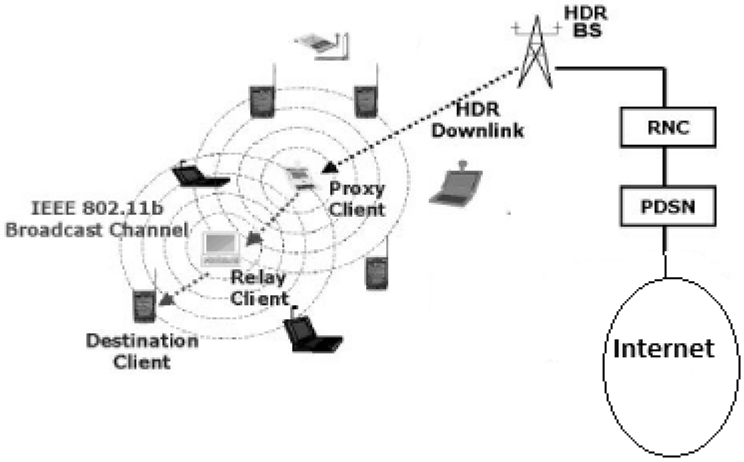

Figure 7 UCAN network architecture

In UCAN, we use the ad-hoc wireless connection exclusively to enhance the performance of a mobile user's access to the cellular infrastructure; in the absence of sufficient connectivity in the ad-hoc network, mobile users continue to access data through their wide-area network interface, albeit at a lower throughput. Figure 7 shows the UCAN network architecture. For those mobile devices associated with the HDR base station, some of them may be actively receiving data packets from the Internet via the HDR downlink, while others may have their HDR interfaces in the dormant mode. Associated clients monitor the pilot bursts of the HDR downlink to estimate their current downlink channel conditions. At the same time, these devices turn on their IEEE 802.11b interfaces in ad-hoc mode, and run UCAN protocols. If a destination client experiences low HDR downlink channel rate (e.g. 38.6Kbps), instead of transmitting directly to the destination, the HDR base station transmits the data frames to another client (proxy client) with a better channel rate (up to 2.4Mbps). These frames are further relayed through IP tunneling via intermediate relay clients to the destination, using the high-bandwidth IEEE 802.11b links.

3.10 The A-Gsm Architecture

The ad hoc GSM is an extension to the GSM cellular architecture for providing extended coverage service to dead spots. It aims to use the existing GSM system modules and entities with minimal changes to providing capability with Existing GSM system. A-GSM architecture defines Q-GSM to A-GSM, GSM to Q-GSM, and A-GSM to GSM handoffs with within a serving BS. The handoff process in A-GSM requires three steps: link quality measurement, initiation or trigger, and handoff control. The link quality measurement aim are aimed at measuring the radio link quality between a given node and its neighbour in addition to measuring the quality of the direct link to the BS if any such direct link exists. A handoff initiation is done based on the signal strength measured at the Q-GSM node. For a GSM call to A-GSM call or an A-GSM call to A-GSM call handoff a mobile controlled handoff is used where the A-GSM nodes make radio measurements and handoff decisions.

4. Conclusions

The objective of this paper is to study the different Hybrid Wireless Networks which are a combination of adhoc wireless networks and cellular networks. The different techniques used in hybrid wireless networks are based on dedicated relay stations and host cum relay stations. From the study it is found that different parameters considered for the design of a hybrid wireless network can be categorized on the basis of spectrum reusability, overlay, throughput enhancement and data forwarding system used which helps in reduced interference, extended coverage, increased reliability etc. The hybrid wireless networks considered in this paper can be further extended or combined to optimize the network performance.

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