An Insight about Current Research Ideas in Wireless Communication-A Review

P.Sunil Kumar[#1], Dr.M.G.Sumithra[#2], Ms.M.Sarumathi[#3]

[#1] P.G.Scholar, Department of ECE, Bannari Amman Institute of Technology, Sathyamangalam
[#2] Professor, Department of ECE, Bannari Amman Institute of Technology, Sathyamangalam
[#3] Assistant Professor, Department of ECE, Bannari Amman Institute of Technology, Sathyamangalam
[#1]sunilprabhakar22@gmail.com

Abstract— In the telecommunications sector, wireless industry has proliferated its growth to such an extent that everyone in the world is a user of some form of developing technology. Wireless communications is one of the most celebrated engineering success stories for the past two decades that has radically changed the life of people. This paper provides a very broad technical view of current research ideas in wireless communication field, emphasizing on the most relevant design applications that could be utilized efficiently. A wide coverage in the areas of research like cognitive radios, opportunistic spectrum sensing, Multiple Input Multiple Output(MIMO) relay networks, technical overview for wireless ad hoc networks, research issues in wireless sensor networks and ultra wideband communications(UWB) is summarized in this paper.

Keywords- MIMO, UWB, Ad hoc, cognitive radios

1. RESEARCH ISSUES IN COGNITIVE RADIOS

The basic conception of software-defined radio (SDR) initiated in the early 1990s, and has now it has become an important core technology for future generation wireless communications. In 1997, the U.S. DoD recommended replacing its 200 families of radio systems with a single family of SDRs in the programmable modular communications system (PMCS) guideline document [1]. The ultimate objective of SDR is to configure a radio platform like a freely programmable computer so that it can adapt to any typical air interface by using an appropriate kind of programming interface. SDR is targeted to implement all kinds of air interfaces and signal processing functions using software in one device. Some of the research ideas in Cognitive radios are listed below.

1.1 MODULATION AND PRIMARY USE RECOGNITION The main research analysis here concentrates on radio signal analysis, modulation recognition and bit stream analysis which are applied to identify whether an alarm corresponds to a primary user, or a secondary user, or noise (false alarm). Modulation recognition is an intermediate step between signal detection and demodulation. Knowledge of the types of the service operating on a channel in a way minimizes overhead to the cognitive radio and its impact on the primary users of the spectrum. A cognitive radio should be able to recognize other cognitive radios on the link channel to prevent them sensing one another as primary users and jumping channels. Modulation recognition can be likelihood-based or feature based [2]. The former is based on the likelihood function of the received signal and the decision is made by comparing the likelihood ratio against a threshold. The likelihood-based algorithms are optimal in the Bayesian sense, they minimize the probability of false classification, but suffer from high computational complexity [33]. The feature-based approach makes decisions based on the observed values of typically, several features. In general, modulation recognition is a challenging task, especially in a non cooperative environment, where no prior knowledge of the incoming signal is available.

1.2 MANAGEMENT OF THE AVAILABLE SPECTRUM Spectrum management functions address four main challenges: spectrum sensing, spectrum decision, spectrum sharing, and spectrum mobility. Spectrum mobility allows a cognitive radio to exchange its frequency of operation in a dynamic manner by allowing the cognitive radios to operate in the best available frequency band seamlessly [22-24]. Spectrum sharing deals with fair spectrum scheduling, which is medium access control MAC functionality. A cognitive radio needs to maintain an up-to-date list of available channels within a band. The channel usage database can also be used to avoid the occupied licensed channels, and a secondary user estimates its position and checks a database to find out which channels are vacant in its vicinity.

1.3 ERASURE CORRECTION CODES A secondary user selects a set of sub channels from the primary user band to establish a secondary user link that adapts itself in accordance with the primary user spectral diversity on that band. The secondary user is required to vacate a sub channel as soon as a primary user becomes active on that sub channel. In order to compensate for this loss, a class of erasure correction codes called LT (Luby Transform) codes or Fountain codes [3] can be used for packet-based channels with erasures before transmitting secondary user packets on these sub channels. This provides packet-level protection at the transport layer or higher, augmenting the bit-level protection that may be provided by the MAC and physical layers.

1.4 AWARENESS OF AVAILABLE SPECTRUM Spectrum awareness over an entire operating bandwidth of interest is a preliminary and very crucial task of a cognitive radio. The sensitivity of cognitive radio is necessary to outperform the primary user receiver by a large margin in order to escape from the hidden terminal problem [18]. This makes spectrum sensing, or spectrum awareness, a very challenging research problem. For cognitive radios, a cross-layer design approach is desirable since the process delay is required to be very minimum. Spectrum awareness can be either passive or active awareness. In passive awareness, the spectrum use pattern is obtained not by sensing with the secondary system itself, but by negotiating with primary users, or from a server or database. The passive awareness approach results in considerable signalling for distribution of frequency information [29]. In active awareness, the secondary user actively senses the frequency spectrum to obtain the spectrum use pattern. Active spectrum awareness can be performed in a non cooperative or cooperative manner. Cooperation helps to cope with the hidden problem. Active spectrum awareness can be either reactive or proactive, depending on how white spaces (unused frequency bands) are searched. Reactive schemes operate on an on-demand basis, where a cognitive radio starts to sense the spectrum only when it has data to send. Proactive schemes, on the other hand, minimize the delay of secondary users by finding an idle band through maintaining a list of licensed bands currently available for opportunistic access through periodic spectrum sensing.

2. RESEARCH ISSUES IN MIMO RELAY NETWORKS

Virtual MIMO schemes can be used to improve communication performance of wireless adhoc networks. Virtual MIMO is a network-based approach. Different nodes in the network can act as elements of an antenna array. As the array elements are not physically connected, a large amount of information must be sent to the combining nodes. In this approach, multiple individual single-antenna nodes cooperate for energy-efficient communications. Examples of virtual MIMO schemes are an Alamouti-encoded scheme for single-hop transmissions[4], a STBC-encoded scheme without perfect synchronization[5], and a clustered topology-based, time-division, DF multirelay, space-time coded MIMO channel for multihop transmissions[6].

2.1 CLUSTERED RELAYING ISSUES A wireless network with fading and a single source-destination pair is considered in an ideal scenario [7]. The information reaches the destination via multiple hops through a sequence of layers of single-antenna relays. Each layer of relays can be treated as virtual MIMO. At high SNR, AF is optimal in terms of degrees of freedom, as it achieves the degrees of freedom equal to that of a point-to-point MIMO system. Hence, lack of coordination in relay nodes does not reduce the achievable degrees of freedom. The performance of this AF strategy degrades with increasing network size. This phenomenon is analysed by finding the tradeoff between network size, rate, and diversity. A cluster-based cooperative strategy using incremental redundancy cooperative coding for slow Rayleigh Fading is also proposed [8].

2.2 DISTRIBUTED STBCs Distributed space-time coding achieves cooperative diversity without CSI at the relays. Using this scheme, antennas of the distributive relays work as transmit antennas of the sender and generate a space-time code at the receiver. It achieves the maximal diversity when the transmit power is infinitely large. Orthogonal STBCs (OSTBCs) are particularly suitable for transmission in the network setting using distributed space-time coding, where each node transmits a different column of the OSTBC matrix [9]. Distributed space-time coding achieves higher diversity always using the same orthogonal designs, when there is more than one relay [10]. Distributed STBCs are designed for wireless networks that have a large set of single-antenna relay nodes, but only a small, a priori unknown subset of nodes is active at any given time [11]. The signal transmitted by an active relay node is the product of an information-carrying code matrix and a unique node signature vector of length Nc. This approach allows convenient exploitation of existing coherent, differential, and non-coherent STBCs originally designed for Nc co-located antennas, and accordingly allows for low-complexity coherent, differential, and non coherent detection. Existing STBCs designed for Nc>2 are co-located antennas which is the most favourable choice for the code matrix, guaranteeing a diversity order of d=min {Ns, Nc} in case of Ns active nodes.

2.3 TRANSMITTER AND RECEIVER COOPERATIONS In [12], capacity improvement from transmitter and receiver cooperation is investigated in a two-receiver network with phase fading and full CSI available at all nodes. The transmitters cooperate by first exchanging messages over an orthogonal transmitter cooperation channel, then encoding jointly with dirty-paper coding [35]. The receivers cooperate by using Wyner-Ziv CF over an analogous orthogonal receiver cooperation channel. Transmitter cooperation outperforms receiver cooperation and improves capacity over non cooperative transmission under most operating conditions when the cooperation channel is strong. However, a weak cooperation channel limits the transmitter cooperation rate; in this case, receiver cooperation is more advantageous. Transmitter and receiver cooperation, i.e., a scheme that uses transmitter-only cooperation at low SNR, whereas at high SNR transmitter cooperation alone captures most of the cooperative capacity improvement [35-37]. Under quasi-static channels, when all the nodes have equal average transmit power along with full CSI, transmitter cooperation is possible whereas the opposite is true when power is optimally allocated among the cooperating nodes but CSI is available only at the receiver.

2.4 DIVERSITY MULTIPLEXING TRADEOFF A general multiple-antenna network with multiple sources, multiple destinations, and multiple relays is considered in [13] in terms of the diversity-multiplexing tradeoff. In case of a full-duplex relay, while DF achieves optimal diversity-multiplexing tradeoff when each of the nodes has one antenna, it may not maintain its good performance when the degrees of freedom in the direct link are increased, whereas CF continues to perform optimally [36]. For a half-duplex relay, CF achieves optimal diversity-multiplexing tradeoff as well. For a system with multiple relays, each node with a single antenna, even under the ideal assumption of full-duplex relays and a clustered network, this virtual MIMO system can never fully mimic a real MIMO diversity-multiplexing tradeoff.

3. RESEARCH ISSUES IN ULTRA WIDEBAND COMMUNICATIONS

UWB technology, also known as impulse radio, was first used to transmit Morse codes by Marconi in 1900 through the transatlantic telegraph. Modern UWB technology has been used for radar and communications since the 1960s. Like CDMA systems, early UWB systems were designed for military covert radar and communications. The early applications of UWB technology were primarily related to radar, driven by the fine-ranging resolution that comes with large bandwidth. UWB technology for wireless communications was pioneered by Scholtz [14]. With the intent of operating UWB in an unlicensed mode that overlaps licensed bands, the FCC issued rules under the FCC Rules and Regulations Part 15 for UWB operation in February 2002. UWB communications are mainly used in rich-scattering indoor environment, which is desired for MIMO implementation. The GHz centre frequency of UWB radio relaxes the requirements on the antenna spacing. As a result, UWB-MIMO, the combination of UWB and MIMO technology is a viable solution for achieving very high data rate, short-range wireless communication. The difficulties in implementation are multipath energy capture, ISI, and the need for high-sampling-rate ADCs. The difficulty in multipath energy capture is due to the extremely low PSD of the UWB signals [31]. This low PSD allows them to share the spectrum with existing RF devices. If a rake receiver is used to collect the multipath energy, a large number of fingers is needed due to the large number of multipath components.

DSSS has a slightly better BER performance than UWB for the same number of users, given the same frequency bandwidth constraint [15]. However, signal processing for CDMA is most difficult due to the very short chip period, and UWB offers a much cheaper solution. For the UWB bandwidth of several gigahertz, a solution using DSSS is impossible.

3.1 DETECTION AND AVOIDANCE ISSUES UWB shares the frequency band with other standards such as the WiMAX (3.4-3.8 GHz) and IEEE 802.11g (5 GHz). The detection and avoidance (DAA) technique is used for solving the interference issues. The UWB transmitter first detects the presence of another active device as well as its likelihood of interference, and avoids that specific band. This allows the UWB system to operate across a continuous range of spectrum [33]. The detection is based on FFT. After a potential interfering signal is detected, a number of techniques can be used to reduce interference- transmit power control, frequency notching, and more advanced techniques. Transmit power control transmits the lowest possible power for reception [32].

3.2 UWB INDOOR CHANNEL ISSUES The IEEE 802.15.3a Task Group recommended a channel model in November 2002[16], which is basically a modified version of the Saleh-Valenzuela model. Model parameters corresponding to several ranges are provided for both LOS and NLOS scenarios. The IEEE 802.15.3a Task Group developed four UWB indoor channel models to support its evaluation of the proposed UWB channels [17]. The IEEE 802.15.3a UWB model could provide reasonably accurate simulation results for UWB channels in vehicular environments [18]. The UWB radio channel around the human body in a typical indoor environment has been measured and modelled in [19]. The body area channel consists of an initial cluster of components diffracting around the body and subsequent clusters of components reflecting from surrounding objects. Components diffracting around the body are well described by a high path loss exponent and correlated lognormal variables. Subsequent clusters have a more complex structure that can be described by a modified Saleh-Valenzuela model. Based on the measurements, a simple statistical channel model is given in [19]. UWB has the attractive features of the time-domain nature of signal transmission. The UWB system can be designed as a single-band or multiband system, with each sub-band greater than 500 MHz. A single sub-band can occupy up to 7,500 MHz UWB spectrum. These schemes generate different performance tradeoffs and design challenges. Early single-band UWB systems generate simple, short pulses with wide spectral occupation. Multiband UWB systems use high-order modulation on constrained bandwidth to enable channelization [34]. The single-band approach is commonly treated as pulsed or carrier-free communications. Information is directly modulated into a sequence of impulse-like waveforms that occupy a bandwidth of up to 7.5 GHz. The single-band approach is the traditional method for UWB implementation.

3.3 RESEARCH ISSUES The pulsed UWB signal can be detected by using conventional receivers. The rake receiver and the matched filter receiver require channel estimation. Different detection [20], transmitted reference (TR) receivers [20, 17, 21], and differential TR receivers [9] do not need channel estimation. A matched filter is equivalent to a rake receiver with infinite fingers and perfect channel estimation. For differential detection systems, the symbols are differentially encoded, and each received data pulse is correlated with the previous one. Each pulse serves as a template for the next. Whatever the receiver architecture, a synchronization circuit must provide accurate information on the arrival times of the incoming pulses. This poses a serious challenge to UWB radios. Single-band pulsed UWB has an inflexible spectrum mask. It also requires very wide-band circuitry that introduces difficulties in implementation, especially in RF-CMOS implementation, and high sampling rates in DACs and ADCs. As with DS-CDMA, a strong interferer may block the wanted signal. The signal-band system is more sensitive to ISI. Multiband UWB is a better choice. Multiband UWB can be implemented as a pulsed multi-band or an MB-OFDM UWB. The multiband system needs an FH strategy for interference avoidance.

4. RESEARCH ISSUES IN WIRELESS ADHOC NETWORKS

As MANET and WSN nodes are energy-restricted equipments, power consumption is a serious and major consideration for a wireless ad hoc network. Power consumption is divided into two parts, firstly, the idle mode and secondly the transmit/receive mode. Power-aware routing is always targeted to increase the lifetime efficiency of the network. It is formulated as an NP-complete problem.

4.1 CAPACITY REGIONS ISSUES Capacity regions for wireless ad hoc networks explain the set of achievable rate combinations between all source-destination pairs in the network under various transmission schemes, such as variable-rate transmission, single-hop or multihop routing, power control, and successive interference cancellation (SIC). Numerical results indicate that multihop routing, the ability for concurrent transmissions, and SIC significantly increase the capacity of ad hoc and multihop cellular networks [23]. On the other hand, gains from power control are emphasized only when variable-rate transmission is not used. Also, time-varying flat-fading and node mobility actually improve the capacity of the networking system. Finally, multihop routing greatly improves the performance of energy-constraint networks.

4.2 ARCHITECTURAL ISSUES A multihop ad hoc network can have either a flat or hierarchial architecture. A flat structure of a huge number of nodes leads to a number of research challenges in terms of organizing the network, collection of the information, throughput fairness, routing, and efficient energy management; that is, a flat structure leads to low scalability and a very complex network-wide coordination. Hierarchial architecture can solve this scalability problem [25]. The process of clustering enables in network data aggregation. Nodes transmit their information and forward it to the destination. A clustering scheme can be identifier-based clustering, topology-based clustering, or energy-based clustering. Periodic re-clustering is applied to select nodes with higher residual energy as cluster heads.

4.3 COVERAGE ISSUES One fundamental issue in wireless ad hoc network is the coverage problem. Coverage is the spatial sensing range of a node. It has to be coordinated among nodes to avoid redundancy, by considering communication distance and other characteristics of sensing tasks. Sensor node placement and dispatch are two important deployment problems in WSNs. The target field may have coverage holes, that is, areas not covered by any node, due to random spatial deployment, presence of obstructions, or node failures. Routing holes, areas devoid of any nodes, may also occur in the deployed topology. A wireless ad hoc network may fail if some of the nodes cannot sense or relay the data.

4.4 QoS FOR WIRELESS ADHOC NETWORKS QoS support in ad hoc networks involves QoS model, QoS resource reservation signalling, QoS routing, and QoS MAC. A QoS signalling coordinates the behaviour of QoS routing, QoS MAC, and other components. The QoS routing process [22] searches for a path with enough resources but does not reserve resources, and thus, resources can be assured when QoS signalling needs to reserve resources. All upper-layer QoS components are dependent on and coordinate with the QoS MAC protocol. Trustworthiness-based QoS routing is a secure routing protocol with QoS support, which include secure route discovery, secure route setup, and trustworthiness-based QoS routing metrics [23].

4.5 CONGESTION CONTROL ISSUES Congestion not only causes packet loss, but also leads to excessive energy consumption. In addition, congestion control is necessary to improve fairness and provide better QoS in case of wireless multimedia networks [24]. Two types of congestion could occur in wireless ad hoc networks. Node-level congestion, caused by buffer overflow in the node, is common in conventional networks. For wireless networks that are based on CSMA-like protocols, link-level congestion may arise. Collisions occur when multiple nodes access the channel at the same time. Congestion can result in packet loss, increased delay, and decrease of both the link utilization and the overall throughput, Retransmissions consume additional energy, which is critical to WSNs. Congestion has a direct impact on energy-efficiency and QoS.

4.6 NETWORK CAPACITY ISSUES With only fixed rate point-to-point communications, finite bandwidth and large power, the transport capacity of a planar network scales the area occupied by the network. Under minimal conditions on the attenuation, and for networks with constant n, the rate per communication pair in a wireless ad hoc network is shown to tend to zero as the number of users gets large [27]. The transmission capacity of a wireless ad hoc network is defined as the maximum spatial intensity of successful transmissions below a specified outage probability. Upper and lower bounds for the transmission capacity of wireless ad hoc networks with SIC receivers are developed in [28], for both perfect and imperfect SIC. Any imperfections in the interference cancellation rapidly degrade its usefulness. Only a few, often just one, interfering nodes need to be cancelled in order to get the majority of the available performance gain.

5. RESEARCH ISSUES IN WIRELESS SENSOR NETWORKS

In addition to the common features of wireless ad hoc networks, WSNs have their own specific nature and features. Many routing, power management, and data dissemination protocols have been designed for WSNs to support practically useful and operable design systems. Management of power has become the need in various scenarios and it is of critical importance. It is aimed at the two fold goal: minimizing the total energy consumption of all nodes in the network and achieving a homogeneous consumption of energy throughput in the network. For WSN design, energy efficiency is treated as the top most priority. The design should also be scalable for large networks. Latency and bandwidth efficiency are of secondary concern, while per-node fairness is usually not considered.

5.1 OPERATING SYSTEMS AND DATABASE ISSUES A sensor node is an embedded system, and an embedded operating system can be used. Middleware is often used to bridge the gap between the operating system and the application. This eases the development of distributed applications. Due to the resource constraints, unreliability of wireless networks, and diversity, middleware for WSN presents a number of new challenges[25-26]. In a data centric approach, each node keeps its data, and nodes execute retrieval and aggregation, with on-demand based operation to deliver the data to external applications. TinyDB supports a data aggregation function via SQL query, which supports selection, projection, determining sampling rate, group aggregation, user-defined aggregation, event trigger, lifetime query, setting storing point and simple joining.

5.2 TIME SYNCHRONIZATION ISSUES It is necessary to provide temporal coordination among all the nodes engaged in a collaborative and distributed interaction. This can be achieved by sending timing messages to the target sensors. Approaches to time synchronization can be categorized as sender-receiver synchronization, receiver-receiver synchronization, and receive-only synchronization [29]. Sender-receiver synchronization is based on two-way message exchanges between a pair of nodes. In receiver-receiver synchronization, the nodes receive a beacon packet from a common sender, and then compare among them their relative clock offset based on their receiving times of the beacon packet. Receive-only synchronization minimizes the use of timing messages for the purpose of saving energy.

5.3 LOCATION ISSUES To be context-aware, location tracking is a major concern in WSNs. This is necessary for monitoring the roaming path of a moving object and determining from which location a measurement came. Location discovery in WSNs poses significant design challenges. Because of constraints in size and cost, it is impractical to use GPS receivers at the sensor nodes. Moreover, WSNs may be deployed in regions where satellite signals may not be available [28-29]. Approaches to WSN location typically deploy a few known nodes called beacons or anchors, which are aware of their own locations.

5.4 SECURITY ISSUES The security of large, densely deployed WSNs requires efficient key distribution and management mechanisms. Security requirements in WSNs are similar to those for ad hoc networks. In addition, WSNs have two specific requirements like survivability which is the ability to provide a minimum level of service in the presence of power exhaustion, failures or attacks and the second factor is the degradation of security services which is again the ability to change security level according to resource availability[26-29]. The security problems may be physical or logical in nature. Physical security problems can be caused by damaged or stolen nodes, inaccurate measurement, jamming, battery exhaustion attacks, as well as malicious nodes. Logical security problems can be due to eavesdropping, injection, attacks to protocols from external or internal nodes, as well as identity and instruction integrity.

5.5 BATTERY TECHNOLOGY ISSUES Battery technologies are important for WSNs. Sensor node lifetime is mainly dependant on the battery lifetime. There are three common battery technologies for WSNs-alkaline, lithium, and nickel metal hydride. The AA alkaline battery provides a cheap, high capacity energy source, but it has a wide voltage range and a large physical size. In addition, lifetime beyond five years is not possible due to battery self-discharge. Lithium batteries provide a very compact power source. They also provide a constant voltage supply that decays little as the battery is drained. Unlike alkaline batteries, lithium batteries are able to operate at temperatures down to -40 degree Celsius. Nickel metal hydride batteries are easily rechargeable, but they have a significant decrease in energy density. If there is no energy-harvesting source, a non-rechargeable battery is a good choice since it has higher energy density. Some designs try to harvest energy from the ambient energy in the form of electromagnetic radiation, heat, or mechanical energy [30]. Energy harvesting techniques are now becoming mature, and both TI and Intel have solar energy harvesting solutions as an access to WSNs.

6. CONCLUSIONS

Wireless industry has become the fastest growing sector of the telecommunications industry, and there is hardly anybody in the world who is not a user of some form of wireless technology. From the most commonly found cell phones, to wireless LANs, to wireless sensors that are proliferating -we are surrounded by wireless communication devices always. This paper gives an overview of the current research ideas in wireless communication technologies. A wide coverage to the research issues that are most relevant to the design of wireless communication and networking systems has been provided.

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