A REVIEW OF FUTURE TRENDS IN THE FIELD OF WIRELESS COMMUNICATION

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ABSTRACT

The demand for high-quality wireless communication services exceeded all expectations in the beginning of this century. The demand will continue to grow in the new millennium. In addition to wireless telephony, wireless data and video transmission will also be required, which clearly will increase the data rate to several megabits per second. In wireless local area networks, the expected data rate is more than 100 M bits/ s.

This paper presents the concept of wireless communication with a simplified classification. Latest research projects in the field of advanced wireless communication have also been given. This is important for design engineers and researchers in the field of wireless communication to know the latest research projects

1. INTRODUCTION

As wireless communication systems evolve, service quality and capacity are of primary importance. To ensure reliable communication over a mobile radio channel, a system must overcome multipath fading, polarization mismatch, and interference. The trend towards low power hand held transceivers increases all of these challenges. Even as more spectrums is allocated, demand for higher data rate services and steadily increasing numbers of users will motivate service providers to seek ways of increasing the capacity of their systems.

Antenna arrays can improve reliability and capacity in two ways. First, diversity combining or adaptive beamforming techniques can combine the signals from multiple antennas in a way that mitigates multipath fading.

Second, adaptive beamforming using antenna arrays can provide capacity improvement through interference reduction. The use of adaptive arrays is an alternative to the expensive approach of cell splitting, which increases capacity by increasing the number of base station sites.

Most adaptive arrays that have been considered for such applications are located at the base station and perform spatial filtering. They cancel or coherently combine multipath components of the desired signal and null interfering signals that have different directions of arrival from the desired signal.

Multi-polarized adaptive arrays, sometimes called polarization-sensitive adaptive arrays, can also match the polarization of a desired signal or null an interferer having the same direction of arrival as the desired signal, if the two signals have different polarization states. Multi-polarized arrays have been considered as a means of rejecting jammers in military applications [1]-[3]. The potential of multi-polarized arrays for interference rejection in wireless communication systems has been investigated in recent years [3]-[6]. There is some indication from the latest researches that 20 to 35 dB of interference rejection is possible if interfering and desired signals differ in either polarization state or angle of arrival. However, neither measurements nor simulations have been reported that show the performance of multi-polarized adaptive arrays in typical mobile multipath channels.

In 1988, Vaughn [7] concluded that with then-current technology, adaptive beamforming would work for units moving at pedestrian speeds but would be difficult for high-speed mobile units. While this was the first publication of its kind, some assumptions were made in

the experiments and data processing that limit the applicability of the results. They are important because many wireless communication systems are characterized by random polarization states due to the random orientations with which users hold the portable handsets.

This paper gives the concept of wireless communication with the easily understandable classification and the latest researches in the field of advanced wireless communication.

Concept of wireless communication can be easily understood by the following points given below [8], [9]:

1.1 Physical Properties of Wireless

- Makes wireless network different from wired networks.
- Should be taken into account by all layers.

1.2 Wireless = Waves

- Electromagnetic radiation
- Emitted by sinusoidal current running through a wire (transmitting antenna)
- Creates propagating sinusoidal magnetic and electric fields according to Maxwell's equations.
- Fields induce current in receiving antenna [8].

1.3 Wave Propagation Example

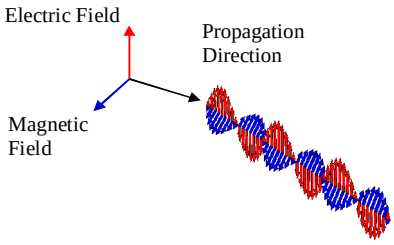

Figure 1 Wave Propagation

1.4 Frequency & Public Use Bands

- Propagating sinusoidal wave with some frequency /wavelength ($f = c / \lambda$).
- C (speed of light) = 3×10^8 m/s.

Name	900 Mhz	2.4 Ghz	5 Ghz
Range	902 - 928	2.4 - 2.4835	5.15 - 5.35
Bandwidth	26 Mhz	83.5 Mhz	200 Mhz
Wavelength	0.33m / 13.1"	0.125m / 4.9"	0.06 m / 2.4"

Table 1 Frequency and Public Used Bands

1.5 Free-space Path-loss

- Power of wireless transmission reduces with square of distance (due to surface area increase of sphere).
- Reduction also depends on wavelength
- Long wave length (low frequency) has less loss
- Short wave length (high frequency) has more loss

1.6 Other Path-loss Exponents

Path-Loss Exponent Depends on environment [8]:

Free space	2
Urban area cellular	2.7 to 3.5
Shadowed urban cell	3 to 5
In building LOS	1.6 to 1.8
Obstructed in building	4 to 6
Obstructed in factories	2 to 3

1.7 Multi-path Propagation

- Electromagnetic waves bounce off of conductive (metal) objects.
- Reflected waves received along with direct wave

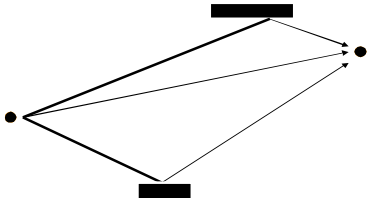

Figure 2 Multi-Path Propagation

1.8 Multi-Path Effect

- Multi-path components are delayed depending on path length (delay spread).
- Phase shift causes frequency dependent constructive / destructive interference

1.9 Modulation

- Modulation allows the wave to carry information by adjusting its properties in a time varying way.
  - Ø Amplitude
  - Ø Frequency
  - Ø Phase
- Digital modulation using discrete "steps" so that information can be recovered despite noise/interference.
  - Ø 8VSB - US HDTV
  - Ø BFSK - Mote Sensor Networks
  - Ø QPSK - 2 Mbps 802.11 & CMDA(IS-95)

1.10 Multi-transmitter Interference:

- Similar to multi-path.
- Two transmitting stations will constructively/destructively interfere with each other at the receiver.
- Receiver will "hear" the sum of the two signals, which usually means garbage.

1.11 Multiple Access Systems

Several cellular radio systems are used to improve spectrum efficiency, allowing more users to employ a channel or frequency band [9] The primary technologies used today are frequency division multiple access (FDMA), time division multiple access (TDMA), and code division multiple access (CDMA). Public safety radio systems primarily use FDMA and TDMA technologies. To better illustrate these technologies, the examples below describe their implementation by the cellular telephone industry.

1.11.1 Frequency Division Multiple Access (FDMA)

The original cellular radio channels were 30 KHz wide and accommodated one voice signal subscriber. As the number of subscribers increased, some cellular radio companies opted to divide the 30 KHz channels into three 10 KHz channels, which would allow a 3:1 increase in subscribers. The process is called frequency division.

Multiple access is accomplished by the cellular radio system control computer having the ability to assign each of the channels to different subscribers. When one subscriber has completed a call or moves into a new cell, the channel may be reassigned to another subscriber

1.11.2 Time Division Multiple Access (TDMA)

Another scheme used by cellular companies is to take the same 30 KHz channel, but instead of dividing it into three narrower channels, it is set up for transmission in three time periods so that three subscribers still use the total 30 KHz; now each subscriber would talk for one-third of the time, thus increasing the number of users by 3:1. By allowing each subscriber to talk for a few milliseconds in rotation, three conversations now take place within the same 30 KHz channel [9].

For time division transmission to work the voice signal must be digitized by a vocoder (voice coder) and each digitized signal is sent in sequence over the 30 KHz spectrum. The subscriber's phone must be perfectly synchronized with the transmission so that it only decodes the desired subscriber's signal in its vocoder. Cell phone and PCS companies have found that by using TDMA, up to eight subscribers may use the same 30 KHz spectrum. Multiple access is accomplished in the same manner as in FDMA above.

Group of special mobile (GSM), which was developed in Europe and is being

used by a number of U.S. companies, provides TDMA transmission with 200 KHz wide channels in the 2 GHz band.

1.11.3 Code Division Multiple Access (CDMA)

CDMA is a digital modulation that uses spectrum spreading techniques and is more complex than either FDMA or TDMA. The transmission spectrum is always much wider than that required for a single transmission, allowing many simultaneous transmissions to be interspersed within the same bandwidth Two types of systems are used: frequency hopping and direct sequence. Both systems use vocoders to digitize the signal.

1.11.3.1 Frequency hopping

The frequency hopping concept is easy to visualize. The transmitter changes frequency every few milliseconds in a prescribed manner as it transmits information. A perfectly synchronized receiver follows the frequency change sequences of the transmitter from one frequency to another to receive the information.

By having as many different frequency changing sequences as there are radios in a given area, many conversations may occur at the same time over the same spectrum. When two transmitter signals collide on the same frequency, the receiving phone transmits a message that it was not received and the original information is resent.

1.11.3.2 Direct sequence

In the direct sequence CDMA, the transmitted digital signals are coded by a "spreading algorithm" in each transmitter. Each receiver has a decoder that deciphers the spread signal and recovers the voice. By using several different spreading codes within each algorithm, this system accommodates many different users at the same time.

2. Latest Researches in Wireless Communication

The research activities of the different groups and research committees are focused on advanced wireless communication systems and architectures needed in the implementation of the above-mentioned systems. Few of the latest research projects has been given below [10]:

2.1 6HOP (Protocols for Heterogeneous Multi-Hop Wireless Ipv6 Networks)

It is a research project under the IST program of European Commission 5th research framework. The project is coordinated by CWC and it started in September 2002. The aim of the project is to specify, design and demonstrate heterogeneous multi-hop wireless IPv6 networks. The WAL (Wire- less Adaptation Layer) concept developed in the previous project WINE (Wireless Internet Networks) will be extended and further developed towards a generic wireless API (Application Programming Interface) and an adaptive protocol framework.

2.2 6NET (Large-Scale International IPv6 Testbed)

It is an EC funded project which aims to build and demonstrate native IPv6 networks and services. The project is coordinated by Cisco who has also provided IPv6 capable routers for the network. The project started in January 2002 and its duration is 36 months. 6NET has more than 30 participants. Additional information is available in http://www.6net.org/.

2.3 The ABRAS (Advanced Baseband Receiver Algorithms for Wideband CDMA Systems)

This project was a multi-year effort studying the implementation of adaptive channel equalizer algorithms for WCDMA terminal receivers. Research covered adaptive algorithm design and analysis as well as their implications on system level performance. A few receiver algorithms have been implemented in the Texas Instruments C6x DSP environment. The project was funded by Nokia and Texas Instruments.

2.4 The FIXWIRE (Fixed Wireless Systems)

This project investigates and develops novel transmission and transceiver technologies for future fixed and low-mobility broadband wireless communication systems. The main focus of the project has been on MIMO techniques, link adaptation, multi carrier modulation and ad-hoc radio networks. The project will last for a number of years and is funded by Elektrobit Ltd.

2.5 FUBS (Future Ultra Wideband Radio Systems)

This is a research project focusing on license-free, ultra wideband (UWB) communication systems. As part of the project, UWB link level system concepts are studied. UWB radio channel measurement and modeling and transceiver implementation also form significant components of the project. A co-existence measurement study with UWB transmitters and WLAN net- works will be performed. FUBS is funded by Nokia, the Finnish Defense Forces Technical Research Centre, Elektrobit Ltd. and Tekes.

2.6 The aim of the FUTURA (Future Radio Access)

This project is to develop basic technology knowledge and expertise needed in creating future communication systems to be used within the next 10-15 years. The emphasis is therefore on the development of general theory and techniques for advanced transceiver algorithms, radio interfaces and wireless network techniques. Particular emphasis will be on adaptive systems utilizing space, time and frequency dimensions and issues related to counteract the effects caused by channel or various sources of interference. The application areas are cellular systems (beyond 3G systems), microwave links, wireless local area networks, short range radio systems, positioning, satellite systems as well as new military communication networks. The project includes three research areas closely connected to each other: radio air interface solutions, transceiver techniques and wireless networks.

2.7 IGLU (Feasibility Study of Indoor Geo-location Concepts)

In this project, novel geo-location solutions for an open terrain training environment are investigated. The project started with a feasibility study on different technologies and indoor radio channel measurements. IGLU is a joint project with an international partner. LEMMINGS were a project to study novel concepts for location based routing and mesh network capability for ad hoc and hybrid ad hoc networking. Study on different routing algorithm possibilities, requirement & validation issues and architecture design were con- ducted during 2001. The project was funded by Nokia. PEMUD (Performance Evaluation of Multi-Dimensional Torus-Knot Codes in Broadband Mobile Communication Channels) aims to create a concept for a software platform that can be used to evaluate the performance of Multi-Dimensional Torus-Knot Codes in broadband mobile communication channels using field measurement data. The project is supported by a venture company in Japan.

2.8 STICS (Space-time coding, modulation and signal processing for future cellular and broadband communication systems)

It is a three-year project funded by the Academy of Finland. The scope of the project is to investigate novel transmission and reception techniques of future wireless systems.

2.9 TRILLIAN / WIRSU

It is a co-operation project which is studying mostly proximity (short-range) wireless communication issues and small devices protocol stacks.

The project is funded by Nokia. ULTRAWAVES (ULTRA Wideband Audio Video Entertainment System) is an EU/IST project with the objective of providing a high performance, low cost wireless home connectivity solution, supporting applications requiring home

multi streaming of high quality video and broadband multimedia. The objective will be to design and implement a complete UWB based system, optimized in terms of throughput, range, in-home/in-building performance and guaranteed multilevel Quos. Other partners in the project are Wisair, Chalmers University of Technology, the University of Roma, Philips and ENSTA.

2.10 WINNER (Wireless Inter-Technology Networks with Optimized Data Rates)

It was a Tekes funded project co-funded by Nokia and the Finnish Defense Forces. It studied networking technologies for future wireless heterogeneous networks. Its research themes included ad hoc routing protocols, hybrid ad hoc network architectures and solutions, and micro-and macro mobility for IPv6 based systems. The Winner project started in May 2000 and it ended at the end of 2002. VTT Electronics participated in WINNER during 2000-2001 as a subcontractor.

The goal of Future Military Radio Communications projects in the TL group is to apply ideas and results based on intensive research made for next generation wireless communications to future military communication systems such as tactical systems, field radio links, wireless LANs, and radiolocation systems. The applicability of the software defined radio concept is also under study.

New results for future tactical military communication systems based on spread spectrum methods have been reported. Different architectures and technical challenges for a software defined radio have been studied. Methods and simulation environments to define the impact of nonlinearities and A/D-conversion have been developed. Performance requirements for a multi-band multi-mode (MBMM) radio have been estimated and methods for hardware capacity estimation have been studied.

Future wireless networks will need improved spectral and energy efficiency. In our strategic research at VTT, we aim at improving the bit rate, in terms of distance, terminal mobility and user density, separately for the downlink and uplink. Thus far we have concentrated on the data and channel estimation algorithms in the receiver [10].

CONCLUSION

This paper presented a brief and critical discussion about wireless communication and related latest researches. Above discussed advanced researches in the field of wireless communication is just a start of the future revolution. By increasing the data rate to several megabits per second the wireless communication will make available a great easiness to the public.

Coordination of different committees and international AWC group report has been also considered in this paper. This paper should help research workers gain a guideline about the wireless communication.

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