

Resource Allocation in Multi Service Wireless Access Network

Final Project -2



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Resource Allocation in Multi-Service Wireless Access Network

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The Divine Force of the Universe

All praise goes to **ALLAH ALMIGHTY**. The most merciful, and the most merciful, and the most beneficent, who gave us courage to complete this task successfully and all respects to **His Prophet MOHAMMED** (peace be upon him) that enable us to recognize our creator.

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Abstract

Wireless Access Networks offer an alternative method for connecting subscribers to the global telecommunication networks. They will become widespread only if they can provide an attractive set of communication services at competitive prices and quality. Fundamental to achieving these goals is how the scarce radio frequency is managed. We evaluate a few alternative resource management principles and highlight some key design issues for such networks. The emphasis is on providing services that require certain minimum performance guarantees in order to be useful. High quality communication services and efficient resource management is only possible if the resource requirements of different services can be adequately described. We propose a framework for expressing wireless communication services in terms upon which radio resource management algorithms can operate. A price/priority component can be used to prioritize between different services. A comparison is made between fixed (FCA) and dynamic (DCA) channel allocation for multi-service TDMA networks. We show that if access networks should be capable of offering high peak-rate services, i.e., requiring more than a few percent of the available frequency spectrum, dynamic channel allocation techniques seem an imperative design component.

Applications that can adapt to varying service levels enable higher resource utilization. The resulting admission control problem is formulated as a *flexible knapsack* problem. A few simple service-pricing models illustrate some tradeoffs involved in defining and pricing new services. Distributed quality-based power control has previously been shown to achieve substantial quality and capacity gains over a constant transmitter power scheme. We compare two classes of quality based power control, differentiated by the rate of the feedback information. A slow power control is preferable when the radio environment changes fast or coding and interleaving can be used to compensate for multi-path fading degradations. A fast scheme is preferred when communication links are established for only short periods, such as when providing busy data services, and for slowly moving terminals. A new technique is also developed to decrease the transmitter power dynamic range when using fast step-wise quality based power control.

We demonstrate that with a suitable set of channel selection and channel access procedures, services for moderately busy data users can be provided without unduly degrading the quality of real-time services. This is possible without splitting of the available frequency resource between different user classes. A novel method is developed to “prepare” channels for rapid channel reassignments. Further, a traffic model for WWW and distributed file system access over wireless links is derived, based on an analysis of the TCP/IP protocol suite.

Introduction

Freedom to communicate irrespective of the time, location and situation is the driving force behind the success of mobile telephony. Mobile phones are rapidly becoming as common to own as a car. The ongoing introduction of new frequency bands around 2GHz for personal communication in Europe, the USA, and Japan will, together with massive marketing from service providers, further drive this trend.

In parallel with the phenomenal growth in mobile telephony, the fixed network is rapidly being upgraded in order to provide new communication services such as electronic mail, WWW browsing, file transfers, voice and music broadcasting and video transmissions. The Internet, originally a data communication network between universities and research institutes, but now increasingly dominated by commercial interests, is serving as a test-bed for many of these new services. The recent surge in interest for words such as cyberspace and information highways also illustrate this trend of increased importance (both culturally and economically) of improved communication services.

In the future, users will want to utilize the above fixed network services, while retaining the freedom of mobility. This can be accomplished by building large networks of access ports. The wireless network will then act as a fixed network extension, through which all the fixed network services can be offered. Instead of cellular radio networks specialized for voice transmissions, we may see networks capable of simultaneously providing, for example, video, voice and file transfer services through a common wire-fewer interfaces

1.1 What is wireless network

Unguided media or wireless communication, transport electromagnetic waves without using a physical conductor. Instead, signals are broadcast through air. (or in a few cases, water), and thus are available to anyone who has a device capable of receiving them.

Wireless networks come in many forms. Some universities are already installing antennas all over the campus to allow students to sit under the trees and consult the library's card catalog. Here the computers communicate directly with the wireless LAN in digital form. Another possibility is using a cellular phone with a traditional analog modem. Direct digital cellular service called CDPD (Cellular Digital Packet Data) is becoming available in many cities.

Also it is possible to have different combinations of wired and wireless networking. For example, think an airplane with a number of people using modems and seatback telephones to call the office. Each call is independent of another. A much more efficient option, however, is the flying LAN in which each seat comes equipped with an ethernet connector into which passengers can plug their computers. A single router on the aircraft maintains a radio link with some router on the ground, changing routers as it flies

along. This configuration is just a traditional LAN, except that its connection to the outside world happens to be a radio link instead of a hardwired line.

1.2 Wireless Systems

The most widespread wireless systems are the broadcasting networks used for distributing radio and television. In these networks the information flow is unidirectional, from a few high power transmitters to a mass of receivers. In this work we will focus on bi-directional wireless access systems, similar in structure to mobile telephony.

The first mobile telephony systems such as NMT, AMPS and TACS were analog, i.e., the transmitted information is not converted to a digital form before transmission. In second-generation systems, speech is converted into a digital form using speech coders. Examples of such systems are the GSM standard, the two originally American standards IS-54 (also known as D-AMPS) and IS-95, and the Japanese PDC standard. The digital CT2, DECT, PHS, and PACS standards are sometimes called *low-tier digital standards*. They use less sophisticated, but more robust and less complex, ADPCM speech coders requiring higher transmission rates.

The current generations of cellular radio systems were mainly designed for voice communication. By using a voice channel, a modem, and a different set of protocols, data transmission rates in the range 2.4 to 19.2 kbps are sometimes available. Such data transmission rates are enough to support short file transfers and facsimile, but are inadequate for applications such as image file or video transfers: these need higher data rates in order to achieve an acceptable transmission delay. Efforts are already under way to provide substantially higher data rates in GSM, both by means of a packet based service (GPRS), and a multi-slot circuit switched service (HSCSD).

1.3 Basic Concepts

A wireless access network provides terminals within the service area with possibility to reach information and other terminals. Ideally, the access network is an interface to globe spanning telephone and data communication networks. Communication can be initiated either from the wireless terminal or from within the fixed network. A terminal can then (with suitable software and hardware) forward or retrieve information streams such as speech, sound, video, text, programs, or combinations thereof. High level applications can use this information flow to provide, for example, a wide range of information and transaction based services.

Another, until now prevalent, but less desirable, way of providing different types of wireless services is to build separate specialized networks, one for each service. Each system can then be fine tuned according to the service's characteristics in order to maximize efficiency. The disadvantage of such an approach is that the cost of building a new network infrastructure each time there is a new service, inhibits the creation of new services. This is caused by the high initial capital investment and the large financial risk with unproven services. Once a network has been built and users have signed up, the

operator is committed to provide service to its subscribers during many years, even if newer technology can offer a similar service better. Permanently splitting up resources between many systems also leads to a lower total resource utilization. Thus, despite the higher service efficiency achieved within each system, the aggregate utility is suboptimal.

Service everywhere within a large geographical area can be achieved by covering it with many wireless access ports (also known as base stations). Careful planning is necessary to ensure that signal strengths are sufficient to enable high quality communication at all locations. The maximal area for which an access port can offer service is called a *cell*. Cells are usually designed to overlap so that an ongoing connection can be transferred from one access port to the next when terminals move. We call this seamless coverage. Cells also need to overlap due to the fact that the electro-magnetic waves from an antenna do not spread out uniformly, but tend to be reflected, amplified (wave guide effect) or shadowed by physical objects in the access port's surroundings.

The primary radio resource is a predefined frequency band of in the electro-magnetic wave spectrum. The band is usually partitioned into a number of sub-bands, called *carrier frequencies*, allowing several users to simultaneously utilize the frequency band. A more fine-grained partitioning of a carrier is possible either by imposing a frame structure with several time slots (time division multiplexing - TDM), or by utilizing orthogonal codes (code division multiplexing -CDM). The acronyms TDMA (time division multiple access) and CDMA (code division multiple access) are often used to categorize systems based on these two principles. For TDMA systems, a single periodically recurring time slot on a frequency carrier is denoted a *unit channel*. For CDMA systems, the term usually refers to a combination of a code and a carrier frequency.

Information that is to be conveyed over a wireless link must be transformed into a signal that is appropriate for the transmission medium. Illustrates the basic principle of digital communications. A block of information represented by a sequence of digital pulses ("ones" and "zeros") is mapped into a waveform more appropriate for the radio medium. This process is known as modulation. The resulting wave is thereafter translated to a permitted carrier frequency and fed to an antenna which emits electro-magnetic waves. At the receiving side the antenna is excited by the electric and magnetic fields created by the emitted wave (and other interfering fields). For successful reception the receiver must be tuned to the correct carrier frequency and know which set of waveforms it should expect. A reverse mapping is performed, resulting in a new digital signal. If the transmitted signal is sufficiently strong and does not get too corrupted by interfering signals, the derived digital signal will be a time delayed version of the transmitted one. Transmission errors can be detected and corrected by including redundant information, i.e. by coding the original message. Different services require different amounts of coding.

1.4 History of wireless networks

In a fact, digital wireless communication is not a new idea. As early as 1901, the Italian physicist Guglielmo Marconi demonstrated a ship-to-store wireless telegraph using Morse Code. Modern Digital wireless systems have better performance, but the basic idea is the same.

1.5 Use of wireless networks

There are so many reasons to use the wireless networks but the most common one is the following. People who need to be online all the time. For these mobile users, twisted pair, coax and fiber optics are of no use. They need to get their hits of data for their laptop, notebook, shirt pocket, palmtop or wristwatch computers without being tethered to the terrestrial communication infrastructure. For these users wireless communication is the answer.

1.6 Advantages and disadvantages of wireless network

It has many advantages. First of all, it is easy to install. Then, it is the portable office. People on the road often want to use their portable electronic equipment to send and receive telephone calls, faxes, and electronic mail, read remote files, login on remote machines and so on; and do this from anywhere on land, sea or air. Besides these, wireless networks are of great value to fleets of trucks, taxis, buses, and repair persons for keeping in contact with home. Another use for rescue workers at disaster sites where the telephone system has been destroyed. Computers there can send messages, keep records, and so on. Finally wireless networks are important for the military. If you have to be able to fight any where on earth on short notice, counting on using the local networking infrastructure is probably not a good idea. It is better to bring your own.

It has also some disadvantages, too. First of all, typically they have a capacity of 1-2 Mbps, which is much slower than wired LANs. The error rates are often much higher, too. Not only these but also the transmissions from different computers can interfere with one another.

2.1 Electromagnetic Spectrum

When electrons move, they create electromagnetic waves that can propagate through free space (even in vacuum). These waves are predicted by the British physicist James Clerk Maxwell in 1865 and first produced and observed by the German physicist Heinrich Hertz in 1887. The number of oscillations per second of an electromagnetic wave is called its frequency, f , and its wavelength, λ , is measured in meters. The frequency (in Hz) and wavelength (in meters) are related by the equation $f\lambda = c$, where c is the speed of light.

By attaching an antenna of the appropriate size to an electrical circuit, the electromagnetic waves can be broadcast efficiently and received by a receiver some distance away. All wireless communications are based on this principle. The amount of information that an electromagnetic wave can carry is related to its bandwidth. At low frequencies it is possible to encode a few bits per second; at higher frequencies at about 500 MHz bandwidth can carry several gigabits per second. The wider the band the higher the data rate.

2.2 Propagation of Radio waves

Radio waves are easy to generate and can travel long distances, penetrate buildings easily. Also these waves are omnidirectional (can travel in all directions). Also they are frequency dependent. At low frequencies power falls off, pass through obstacles well. At high frequencies, they travel straight lines, bounce off obstacles and also they can be absorbed by rain.

2.3 Types of Propagation

Radio wave transmission utilizes five different types of propagation:

Surface

- Tropospheric
- Ionospheric
- Line of sight
- Space

Radio technology considers the earth as surrounded by two layers of atmosphere: the troposphere and the ionosphere. The troposphere is the portion of the atmosphere extending outward approximately 30 miles from the earth's surface and contains what we generally think of as air. Clouds, winds, temperature variations, and weather in general occur in the troposphere, as does jet plane travel. The ionosphere is the layer of atmosphere above the troposphere but below space. It is beyond what we think of as atmosphere and contains free electrically charged particles.

2.4 Surface propagation

In surface propagation, radio waves travel through the lowest portion of the atmosphere, hugging the earth. At the lowest frequencies, signals emanate in all directions from the transmitting antenna and follow the curvature of the planet. Distance depends on the amount of power in the signal: the greater the power the greater the distance. Surface propagation can also take place in seawater.

2.5 Tropospheric Propagation

It can work two ways. Either a signal can be directed in a straight line from antenna to antenna or it can be broadcast at an angle into the upper layers of the troposphere where it is reflected back down to earth's surface. The first method requires that the placement of the receiver and the transmitter be within line of sight distances, limited by the curvature of the earth in relation to the height of the antennas. The second method allows greater distances to be covered.

2.6 Ionospheric Propagation

In ionospheric propagation, higher frequency radio waves radiate upward into the ionosphere where they are reflected back to earth. The density difference between the troposphere and the ionosphere causes each radio wave to speed up and change direction, bending back to earth. This type of transmission allows for greater distances to be covered with lower power output.

2.7 Line-of-Sight Propagation

In line-of-sight propagation, very high frequency signals are transmitted in straight lines directly from antenna to antenna. Antennas must be directional, facing each other, and either tall enough or close enough together not to be affected by the curvature of the earth. Line-of-sight propagation is tricky because radio transmissions can not be completely focused. Waves emanate upward and downward as well as forward and can reflect off the surface of the earth or parts of the atmosphere. Reflected waves that arrive at the receiving antenna later than the direct portion of the transmission can corrupt the received signal.

2.8 Space Propagation

It utilizes satellite relays in place of atmospheric refraction. A broadcast signal is received by an orbiting satellite, which rebroadcasts the signal to the intended receiver back on the earth. Satellite transmission is basically line-of-sight with an intermediary (the satellite). The distance of the satellite from the earth makes it the equivalent of a super high gain antenna and dramatically increases the distance coverable by a signal.

2.9 Propagation of specific Signals

The type of propagation used in radio transmission depends on the frequency (speed) of the signal. Each frequency is suited for a specific layer of the atmosphere and is most efficiently transmitted and received by technologies adapted to that layer.

2.9.1 VLF Very Low Frequency

Its waves are propagated as surface waves, usually through air but sometimes through seawater. VLF waves do not suffer much attenuation in transmission but are susceptible to the high levels of atmospheric noise (heat and electricity) active at low altitudes. VLF waves are used mostly for long range radio navigation and for submarine communication.

2.9.2 LF Low Frequency

Similar to VLF, low frequency waves are also propagated as surface waves. LF waves are used for long range radio navigation and for radio beacons or navigational locators. Attenuation is greater during the daytime, when absorption of waves by natural obstacles increases.

2.9.3 MF Middle Frequency

Middle Frequency signals are propagated in the troposphere. These frequencies are absorbed by the ionosphere. The distance they can cover is therefore limited by the angle needed to reflect the signal within the troposphere without entering the ionosphere. Absorption increases during the daytime, but most MF transmissions rely on line-of-sight antennas to increase control and avoid the absorption problem altogether. Uses for MF transmissions include AM radio, maritime radio, radio direction finding (RDF), and emergency frequencies.

2.9.4 HF High Frequencies

High frequency signals use ionospheric propagation. These frequencies move into the ionosphere, where the density difference reflects them back to earth. Uses for HF signals include amateur radio (ham radio), citizen's band (CB) radio, international broadcasting, military communication, long distance aircraft and ship communication, telephone, telegraph, and facsimile.

2.9.5 VHF Very High Frequency

Very high frequency waves use line-of-sight propagation. Uses for VHF include VHF television, FM radio, aircraft AM radio, and aircraft navigational aid.

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2.9.6 UHF Ultra High Frequency

Ultra high frequency waves always use line-of-sight propagation .Uses for UHF include UHF television, mobile telephone, cellular radio, paging ,and microwave links.Note that microwave communication begins at 1 GHz in the UHF band and continues into the SHF and EHF bands.

2.9.7 SHF Super High Frequency

Superhigh frequency waves are transmitted using mostly line-of-sight and some space propagation.Uses for SHF include terrestrial and satellite microwave and radar communicaiton.

2.9.8 EHF Extremely High Frequency

These waves use space propagation .Uses for EHF are predominantly scientific and include radar, satellite, and experimental communications.

2.10 MICROWAVE TRANSMISSION

Above 100 MHz the waves travel in straight lines and therefore can be narrowly focused.Concentrating all the energy into a small beam using a parabolic antenna gives much a higher signal to noise ratio,but the transmitng and receiving antennas must be accurately aligned with each other.In addition, this directionality allows multiple transmitters lined up in a row to communicate with multiple resources in a row with interference.Before fiber optics, for decades microwaves formed the heart of long distance telephone transmission system. In fact the long distance carrier MCI's name first stood for Microwave communications, because its entire system was originally built on microwave towers.

Since the microwaves travel in straight line, if the towers are too far apart, the earth will get in the way.Consequently repeaters are needed peridically.The higher the towers are, the further apart they can be.The distance between repeaters goes up very roughly with the square root of the tower height.For 100m high towers, repeaters can be spaced 80 km apart.

Unlike radio waves at lower frequencies, microwaves do not pass through buildings well.In addition, even though the beam may be well focused at the transmitter,there is still some divergence in space.Some waves may be refracted off low lying atmospheric layers and may take slightly longer to arrive than direct waves.The delayed waves may arrive out of phase with the direct wave and thus cancel the signal.This effect is called "multipath fading" and is often a serious problem.It is weather and frequency dependent.Some operators keep 10 percent of their channels idle as spares to switch on when multipath fading wipes out some frequency band temporarily.

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The demand for more and more spectrum works to keep improving the technology so transmission can use still higher frequencies. Bands up to 10 GHz are now in routine use, but at about 8 GHz a new problem sets in: absorption by water. These waves are only a few centimeters long and are absorbed by rain. This effect would be fine if one were planning to build a huge outdoor microwave oven, but for communication, it is a severe problem. As with multipath fading the only solution is to shut off links that are being rained on and route around them.

In summary microwave communication is so widely used for long distance telephone communication, cellular phones, television distribution, and other uses that a severe shortage of spectrum has developed. It has several significant advantages over fiber:

- The main one is that no right of way is needed, and by buying a small plot of ground every 50 km and putting a microwave tower on it, one can bypass the telephone system and communicate directly.
- Microwave is also inexpensive. Putting up two simple towers and putting antennas on each one may be cheaper than burying 50 km of fiber through a congested urban area or up over a mountain, and it may also be cheaper than leasing the telephone company's fiber, especially if the telephone company has not yet even fully paid for the copper it ripped out when it put in the fiber.

In addition to being used for long distance transmission, microwaves have another important use, namely, the Industrial/Scientific/Medical bands. These bands form the one exception to the leasing rule: transmitters using these bands do not require government licensing. One band is allocated world wide : 2.400-2.484 GHz. In addition, in the United States and Canada, bands also exist from 902-928 MHz and from 5.725-5.850 GHz. These bands are used for cordless telephones, garage door openers, wireless hi-fi speakers, security gates... The 900 MHz band works best but is crowded and equipment using it may only be operated in North America. The higher bands require more expensive electronics and are subject to interference from microwave ovens and radar installations. Nevertheless these bands are popular for various forms of short range wireless networking because they avoid the problems associated with licensing.

2.11 Repeaters

To increase the distance served by terrestrial microwave, a system of repeaters can be installed with each antenna. A signal received by one antenna can be converted back into transmittable form and relayed to the next antenna. The distance required between repeaters varies with the frequency of the signal and the environment in which the antennas are found. A repeater may broadcast the regenerated signal either at the original frequency or at a new frequency, depending on the system.

Wireless Access Method And Techniques

2.12 Antennas

Two types of antennas are used for terrestrial microwave communications: parabolic dish and horn. A parabolic dish antenna is based on the geometry of a parabola: every line parallel to the line of symmetry reflects off the curve at angles such that they intersect in a common point called the focus. The parabolic dish works like a funnel, catching a wide range of waves and directing them to a common point. In this way, more of the signal is recovered than would be possible with a single point receiver.

Outgoing transmissions are broadcast through a horn aimed at the dish. The microwaves hit the dish and are deflected outward in a series of narrow parallel beams by the curved head. Received transmissions are collected by the scooped shape of the horn, in a manner similar to the parabolic dish and are deflected down into the stem.

2.13 SATELLITE COMMUNICATION

Satellite transmission is much like line-of-sight microwave transmission in which one of the stations is a satellite orbiting the earth. The principle is the same as terrestrial microwave, with a satellite acting as a supertall antenna and repeater. Although in satellite transmission signals must still travel in straight lines, the limitations imposed on distance by the curvature of the earth are reduced. In this way satellite relays allow microwave signals to span continents and oceans with a single bounce. Satellite microwave can provide transmission capability to and from any location on earth, no matter how remote. This advantage makes high quality communication available to undeveloped parts of the world without requiring a huge investment in ground based infrastructure. Satellites themselves are extremely expensive, of course, but leasing times or frequencies on one can be relatively cheap.

2.14 Geosynchronous Satellites

According to Kepler's law, the orbital period of a satellite varies as the orbital radius to the $3/2$ power. Near the surface of the earth, the period is about 90 mi. within sight of any given ground station for only a short time interval.

However at an altitude of approximately 36000 km above the equator, the satellite period is 24 hours, so it revolves at the same rate as the earth under it. An observer looking at a satellite in a circular equatorial orbit sees the satellite hang in a fixed spot in the sky, apparently motionless. Having the satellite be fixed in the sky is extremely desirable, because otherwise an expensive steerable antenna would be needed to track it.

With current technology, it is unwise to have satellites spaced much closer than 2 degrees in the 360-degree equatorial plane, to avoid interference. With a spacing of two degrees, there can only be $360/2=180$ geosynchronous communication satellites in the sky at once. Some of these orbit slots are reserved for other classes of users.