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LONERE – RAIGAD -402 103
Mid Semester Examination – October - 2017

Branch:M.Tech (Electronics & Communication Engineering) Sem.:- I

Subject(Code):- Wireless Communication (MTECC102) Marks: 20

Date:- Time:- 1 Hr.

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MODEL ANSWERS (Marks)

Q.No.1a.) Explain in brief requirements for the wireless services (08)

Solution: Requirements for the Services

1 Data Rate **1 Mark**

• *Sensor networks* usually require data rates from a few bits per second to about 1 Kbit/s. typically;a sensor measures some critical parameter, like temperature, speed, etc., and transmits the currentvalue (which corresponds to just a few bits) at intervals that can range from milliseconds to severalhours. Higher data rates are often required for the central nodes of sensor networks that collectthe information from a large number of sensors and forward it for further processing. In thatcase, data rates of up to 10Mbit/s can be required.

• *Elementary data services* require between 10 and 100 Kbit/s. One category of these services usesthe display of the cellphone to provide Internet-like information. Since the displays are smaller,the required data rates are often smaller than for conventional Internet applications. Anothertype of data service provides a wireless mobile connection to laptop computers

• *High-speed data services*: WLANs and 3G cellular systems are used to provide fast Internetaccess, with speeds that range from 0.5 to 100 Mbit/s (currently under development).

2 Range and Number of Users **1 Mark**

• *Body Area Networks* (BANs) cover the communication between different devices attached to onebody – e.g., from a cellphone in a hip holster to a headset attached to the ear. The range is thuson the order of 1m. BANs are often subsumed into PANs.

• *Personal Area Networks* include networks that achieve distances of up to or about 10 m, coveringthe "personal space" of one user. Examples are networks linking components of computers andhome entertainment systems. Due to the small range, the number of devices within a PAN issmall, and all are associated with a single "owner." Also, the number of overlapping PANs (i.e.,sharing the same space or room) is small – usually less than five. That makes cell planning andmultiple access much simpler.

• *Cellular systems* have a range that is larger than, e.g., the range of WLANs. Microcells typicallycover cells with 500m radius, while macro cells can have a radius of 10 or even 30 km.

<u>3 Mobility</u> **2 Mark**

• *Fixed devices* are placed only once, and after that time communicate with their BS, or witheach other, always from the same location. The main motivation for using wireless transmissiontechniques for such devices lies in avoiding the laying of cables. Even though the devices arenot mobile, the propagation channel they transmit over can change with time:

• *Low mobility*: many communications devices are operated at pedestrian speeds. Cordless phones,as well as cellphones operated by walking human users are typical examples. The effect of the lowmobility is a channel that changes rather slowly, and – in a system with multiple BSs – handoverfrom one cell to another is a rare event.

• *High mobility* usually describes speed ranges from about 30 to 150 km/h. Cellphones operatedby people in moving cars are one typical example.

• *Extremely high mobility* is represented by high-speed trains and planes, which cover speedsbetween 300 and 1000 km/h. These speeds pose unique challenges both for the design of thephysical layer (Doppler shift, see Chapter 5) and for the handover between cells.

<u>4 Energy Consumption</u> **1 Mark**

Energy consumption is a critical aspect for wireless devices. Most wireless devices use (one-way orrechargeable) batteries, as they should be free of *any* wires – both the ones used for communicationand the ones providing the power supply.

• *Rechargeable batteries*: nomadic and mobile devices, like laptops, cellphones, and cordlessphones, are usually operated with rechargeable batteries. Standby times as well as operatingtimes are one of the determining factors for customer satisfaction. Energy consumption is determinedon one hand by the distance over which the data have to be transmitted (remember that aminimum SNR has to be maintained), and on

the other hand, by the amount of data that are to betransmitted (the SNR is proportional to the energy per bit).

5 Use of Spectrum **1 Mark**

• ***Spectrum dedicated to service and operator*****: in this case, a certain part of the electromagneticspectrum is assigned, on an exclusive basis, to a service provider. A prime point in case is cellulartelephony, where the network operators buy or lease the spectrum on an exclusive basis (oftenfor a very high price). Due to this arrangement, the operator has control over the spectrum andcan plan the use of different parts of this spectrum in different geographical regions, in order tominimize interference.**

Spectrum allowing multiple operators**:**

◦ ***Spectrum dedicated to a service*****: in this case, the spectrum can be used only for a certainservice (e.g., cordless telephones in Europe and Japan), but is not assigned to a specificoperator. Rather, users can set up qualified equipment without a license.**

◦ ***Free spectrum*****: is assigned for different services as well as for different operators. The ISMband at 2.45 GHz is the best known example – it is allowed to operate microwave ovens, WiFi LANs, and Bluetooth wireless links, among others, in this band.**

• ***Ultra Wide Bandwidth systems*** **(UWB) spread their information over a very large bandwidth,while at the same time keeping a very low-power spectral density. Therefore, the transmit bandcan include frequency bands that have already been assigned to other services, without creatingsignificant interference.**

6 Direction of Transmission **1 Mark**

• ***Simplex systems*** **send the information only in one direction – e.g., broadcast systems and pagers.•** ***Semi-duplex systems*** **can transmit information in both directions. However, only one direction isallowed at any time. Walkie-talkies, which require the user to push a button in order to talk, area typical example.**

• ***Full-duplex systems*** **allow simultaneous transmission in both directions – e.g., cellphones andcordless phones.•** ***Asymmetric duplex systems*****: for data transmission, we often find that the required data rate inone direction (usually the downlink) is higher than in the other direction. However, even in thiscase, full duplex capability is maintained.**

7 Service Quality **1 Mark**

The requirements for service quality also differ vastly for different wireless services. The first main indicator for service quality is ***speech quality*** **for speech services and** ***file transfer speed*** **for dataservices. Speech quality is usually measured by the** ***Mean***

Opinion Score **(MOS). Thespeed of data transmission is simply measuredin bit/s – obviously, a higher speed is better.**

Q.No.1b.) Derive the equation for received power P_r of the Free Space Propagation model. (08)

Solution:

Free space power received by a receiver antenna separated from a radiating transmitter antenna by a distance d is given by Friis free space equation:

$$P_r(d) = (P_t G_t G_r l^2) / ((4p)^2 d^2 L)$$ **[Equation 1] 1 Mark**

P_t is transmitted power
$P_r(d)$ is the received power
G_t is the transmitter antenna gain (dimensionless quantity)
G_r is the receiver antenna gain (dimensionless quantity)
d is T-R separation distance in meters
L is system loss factor not related to propagation (L>= 1)
L = 1 indicates no loss in system hardware (for our purposes we will take L = 1, so we will igonore it in our calculations).
l is wavelength in meters.

The gain of an antenna G is related to its affective aperture A_e by: 1 Mark

$$G = 4pA_e / l^2$$ **[Equation 2]**

The effective aperture of A_e is related to the physical size of the antenna, l is related to the carrier frequency by:

$$l = C/F = 2pc / WC$$ **[Equation 3]**

F is carrier frequency in Hertz
WC is carrier frequency in radians per second.
C is speed of light in meters/sec

The *effective isotropic radiated power* (EIRP) is defined as:

$$EIRP = Pt\,Gt$$ **[Equation 4] 1 Mark**

Path loss, which represents signal attenuation as positive quantity measured in dB, is defined as the difference (in dB) between the effective transmitted power and the received power.

PL(dB) = 10 log (Pt/Pr) = -10log[(GtGrl2)/(4p)2d2] [Equation 5]

If antennas have unity gains (exclude them) 2 Mark PL(dB) = 10 log (Pt/Pr) = -10log[l2/(4p)2d2] [Equation 6]

The far-field, or Fraunhofer region, of a transmitting antenna is defined as the region beyond the far-field distance df given by:

df = 2D2/l [Equation 7]

D is the largest physical dimension of the antenna.

Additionally, df >> D and df >> l 1 Mark

Received power Pr(d), at a distance d > d0 from a transmitter, is related to Pr at d0, which is expressed as Pr(d0).

The power received in free space at a distance greater than d0 is given by:

Pr(d) = Pr(d0)(d0/d)2 d >= d0 >= df

Expressing the received power in dBm and dBW 2 Mark

Pr(d) (dBm) = 10 log [Pr(d0)/0.001W] + 20log(d0/d)

where d >= d0 >= df and Pr(d0) is in units of watts.

Pr(d) (dBW) = 10 log [Pr(d0)/1W] + 20log(d0/d)

where d >= d0 >= df and Pr(d0) is in units of watts.

Q. No. 2a.) Explain handover strategies (04)

Solution: 1 Mark

When a mobile moves into a different cell while a conversation is in progress, the MSC automatically transfers the call to a new channel belonging to the new base station. System designers must specify an optimum signal level at which to initiate a handoff. Once a particular signal level is specified as the minimum usable signal for acceptable voice quality at the base station receiver (normally taken as between —90 dB m and —100 dB m), a slightly stronger signal level is used as a threshold at which a handoff is made. This margin, given by $\Delta = P_{r\ handoff} - P_{r\ minimum\ usable}$ cannot be too large or too small.

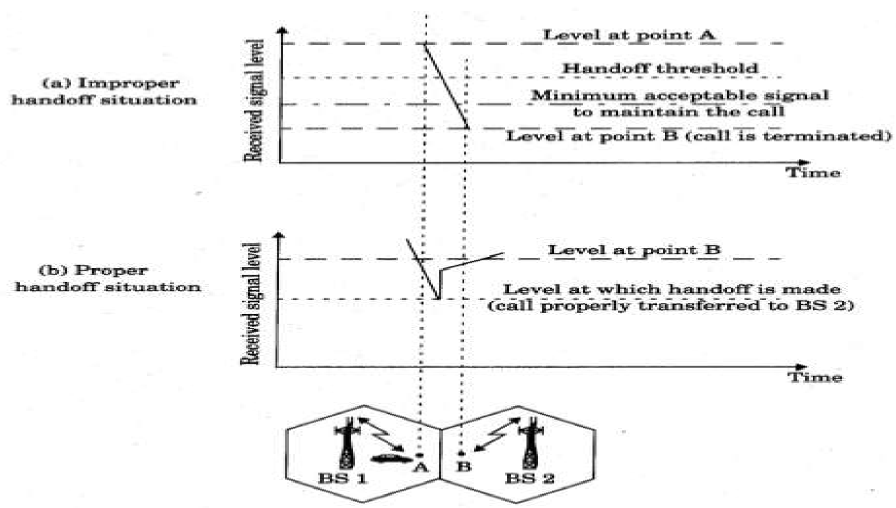
Δ

Δ

If Δ is to large, unnecessary handoffs which burden the MSC may occur, and if Δ is to small, there may be insufficient time to complete a handoff before a call is lost due to weak signal conditions. Therefore, Δ is chosen carefully to meet these conflicting requirements.

Figure 2.3 illustrates a handoff situation. 2 Marks

Figure demonstrates the case where a handoff is not made and the signal drops below the minimum acceptable level to keep the channel active. This dropped call event can happen when there is an excessive delay by the MSC in assigning a handoff, or when the threshold z\ is set too small for the handoff time in the system. Excessive delays may occur during high traffic conditions due to computational loading at the MSC or due to the fact that no channels are available on any of the nearby base stations (thus forcing the MSC to wait until a channel in a nearby cell becomes free).



The length of time needed to decide if a handoff is necessary depends on the speed at which the vehicle is moving. If the slope of the short-term average received signal level in a given time interval is steep, the handoff should be made quickly. The time over which a call may be maintained within a cell, without handoff, is called the dwell time.

A) Prioritizing Handoffs 1 Mark

One method for giving priority to handoffs is called the guard channel concept, whereby a fraction of the total available channels in a cell is reserved exclusively for handoff requests from ongoing calls which may be handed off into the cell. This method has the disadvantage of reducing the total carried traffic, as fewer channels are allocated to originating calls. Guard channels, however, offer efficient spectrum utilization when dynamic channel assignment strategies, which minimize the number of required guard channels by efficient demand based allocation, are used.

B) Practical Handoff Considerations

In practical cellular systems, several problems arise when attempting to design for a wide range of mobile velocities. High speed vehicles pass through the coverage region of a cell within a matter of seconds, whereas pedestrian users may never need a handoff during a call. Particularly with the addition of microcells to provide capacity, the MSC can quickly become burdened if high speed users are constantly being passed between very small cells. Several
Schemes have been devised to handle the simultaneous traffic of high speed and another practical limitation is the ability to obtain new cell sites.

Q. No. 2b.) Explain the basic principle of frequency reuse for both regulated And unregulated access.

(04)

Solution:

A) Frequency Reuse in Regulated Spectrum ***2Marks***

Since spectrum is limited, the *same* spectrum has to be used for *different* wireless connections in *different* locations. Let us consider in the following a cellular system
Where different connections (different users) are distinguished by the frequency channel (band around a certain carrier frequency) that they employ. If an area is served by a single BS, then the available spectrum can be divided into *N* frequency channels that can serve *N* users simultaneously. If more than *N* users are to be served, multiple BSs are required, and frequency channels have to be reused in different locations.

For this purpose, we divide the area (a region, a country, or a whole continent) into a number of *cells*; we also divide the available frequency channels into several groups. The channel groups are now assigned to the cells. The important thing is that channel groups can be used in multiple cells. The only requirement is that cells that use the same frequency group do not interfere with each Other *significantly*. It is fairly obvious that the same carrier frequency can be used for different connections.

But in order to achieve high efficiency, frequencies must actually be reused much more often – typically, several times within each city. Consequently, *intercell Interference* (also known as *co-channel interference*) becomes a dominant factor that limits transmission quality. Spectral efficiency describes the effectiveness of reuse – i.e., the traffic density that can be achieved per unit bandwidth and unit area. for voice traffic and bit/(s) for data. Since the area covered by a network provider, as well as the Bandwidth that it can use, are fixed, increasing the spectral efficiency is the only way to increase the number of customers that can be served, and thus revenue. Methods for increasing this spectral efficiency are thus at the center of wireless communications research. Since a network operator buys a license for a spectrum, it can use that spectrum according to its own planning.

B) Frequency Reuse in Unregulated Spectrum ***2Marks***

In contrast to regulated spectrum, several services use frequency bands that are available to the general public. For example, some WLANs operate in the 2.45-GHz band, which has been assigned to "ISM" services. Anybody is allowed to transmit in these bands, as long as they (i) limit the emission power to a prescribed value, (ii) follow certain rules for the signal shape and bandwidth, and (iii) use the band according to the (rather broadly defined) purposes stipulated by the frequency regulators.

As a consequence, a WLAN receiver can be faced with a large amount of interference. This interference can either stem from other WLAN transmitters or from microwave ovens, cordless phones, and other devices that operate in the ISM band. For this reason, a WLAN link must have the capability to deal with interference. That can be achieved by selecting a frequency band within the ISM band at which there is little interference, by using spread spectrum techniques.

There are also cases where the spectrum is assigned to a specific service (e.g., DECT), but not to a specific operator. In that case, receivers might still have to deal with strong interference, but the structure of this interference is known. Dynamic frequency assignment can be seen as a special case of *cognitive radio*

Q.No. 2c.) Consider the downlink of a GSM system (see also Chapter 24). The carrier frequency is 950MHz and the RX sensitivity is (according to GSM specifications) −102 dB m. The output power of the TX amplifier is 30 W. The antenna gain of the TX antenna is 10 dB and the aggregate attenuation of connectors, combiners, etc. is 5 dB. The fading margin is 12 dB and the breakpoint b_{reak} is at a distance of 100 m. What distance can be covered? (04)

Solution:

TX side: 1 Mark

TX power	***P*TX 30W**	**45 dB m**
Antenna gain	***G*TX 10**	**10 dB**
Losses (combiner, connector, etc.)	***L*f −5dB**	
EIRP (Equivalent Isotropic ally Radiated Power) 50 dB m		

RX side: 1 Mark

RX sensitivity	***P* min**	**−102 dB m**
Fading margin		**12 dB**
Minimum RX power (mean)		**−90 dB m**
Admissible path loss (difference EIRP and min. RX power)		**140 dB**
Path loss at d_{break}= 100m	$[\lambda/(4\pi d)]^2$	**72 dB**
Path loss beyond breakpoint	d^{-n}	**68 dB**

Depending on the path loss exponent, **2 Mark**

n = 1.5 . . . 2.5 (line-of-sight) 3

n = 3.5 . . . 4.5 (non-line-of-sight)

We obtain the coverage distance,

$d$cov= 100 1068/(10n)m (3.9)

If, e.g., n = 3.5, then the coverage distance is 8.8 km.

Q. No. 2d.) Write a short note on Narrowband Models (04)

Solution:

1. ***Modeling of Small-Scale and Large-Scale Fading*** **2 Marks**

For a narrowband channel, the impulse response is a delta functions with a time-varying attenuation, so that for slowly time-varying channels:

$$h(t, \tau) = \alpha(t)\delta(\tau)$$

The variations in amplitude over a small area are typically modeled as a random process, with an autocorrelation function that is determined by the Doppler spectrum. The complex amplitude is modeled as a zero-mean, circularly symmetric complex Gaussian random variable. As this gives rise to a Rayleigh distribution of the absolute amplitude, we henceforth refer to this case simply as "Rayleigh fading." When considering variations in a somewhat larger area, the small-scale averaged amplitude F obeys a lognormal distribution, with standard deviation σ F; typically, values of σ F are 4 to 10 db. The spatial autocorrelation function of lognormal shadowing is usually assumed to be a double-sided exponential, with correlation distances between 5 and 100 m, depending on the environment.

2. Path Loss Models **2 Marks**

Next, we consider models for the received field strength, averaged over both small-scale and the large-scale fading. This quantity is modeled completely deterministically. The most simple models of that kind are the free space path loss model, and the "breakpoint" model (with $n = 2$ valid for distances up to $d < d_{break}$, and $n = 4$ beyond that, as described in Chapter 4). In more sophisticated models, described below, path loss depends not only on distance but also on some additional external parameters like building height, measurement environment (e.g., suburban environment), etc.

. Path loss (in dB) is written as

$$PL = A + B \log(d) + C \quad (7.2)$$

Where A, B, and C are factors that depend on frequency and antenna height.

Factor A increases with carrier frequency and decreases with increasing height of the BS and Mobile Station (MS). Also, the path loss exponent (proportional to B) decreases with increasing height of the BS. The model is only intended for large cells, with the BS being placed higher than the surrounding rooftops.