FINAL EXAMINATION - ANSWERS

WIRELESS NETWORKS (CSC 418)

INSTRUCTION TO STUDENTS: ATTEMPT ALL QUESTIONS. TIME: 3 HOURS

1. **What do you understand by the following terms? (30mks)**
   i. **Wireless local area networks (WLAN)** – This is wireless local area network that links two or more devices using wireless communication (no communication cables between the devices) to form a local area network within a limited area as a home, school, computer laboratory, office, campus building etc.
   ii. **Wireless Personal area network (WPAN)** – This is wireless personal area network that links two or more devices like the WLAN but now on a more personal level. An example is Bluetooth connection between two cell phone devices to communicate and/ or share data (like wearables such as the communication between a smart watch and a phone). In these types of connections there is the master device that is supplying the data and the slave device that is receiving the data.
   iii. **Mobile AD HOC Network (MANETs) –** This is a self-configuring network of mobile routers (and associated hosts) connected by wireless links, the union of which form an arbitrary topology
   iv. **CDMA:** Code Division Multiple Access. - CDMA refers to a multiple access method in which the individual terminals use spread-spectrum techniques and occupy the entire spectrum whenever they transmit. CDMA is a method in which users share time and frequency allocations, and are channelized by unique assigned codes. The signals of different users are separated at the receiver by using a correlator that captures signal energy only from the desired user or channel.
   v. **Duplexing –** This refers to how transmission and reception events are multiplexed together.
   vi. **Wireless ATM (Asynchronous transfer mode) –** This is a high-performance connection-oriented switching and multiplexing technology that uses fixed packets to transport a wide range of integrated services over a single network (wirelessly).
   vii. **Wireless Sensor Networks -** this is a network composed of large number of small, low power, low-cost devices called sensors. The main task of WSNs is to monitor and report environmental conditions. The main characteristics of WSNs is that all the sensors belong to a group and work toward a common goal. An individual sensor has little value of its own unless it works in cooperation with other sensors in a distributed fashion. They exchange messages frequently according to the application demands and report the information to a single or to multiple sinks.
   viii. **Back pressure routing** – This refers to an algorithm for dynamically routing traffic over a multi-hop network by using congestion gradients. It usually refers to a data network but can apply to other types of networks as well.

ix. **Opportunistic routing -** Opportunistic routing is a new paradigm in routing for wireless sensor network which chooses the node closest to the target node for forwarding the data. It uses the broadcasting nature of wireless sensor networks. Opportunistic routing has increased the efficiency, throughput and reliability of sensor networks

x. **Transmission control protocol (TCP) –** This is a connection-oriented transport protocol which provides a reliable byte stream to the application layer. Application data submitted to the TCP is divided into protocol data units (PDUs) called segments, before transmission.

2. Discuss the following characteristics of wireless communication channel. (10mks)

1. Path loss
2. Fading and shadowing
3. Interference
4. Doppler shift

Path loss

Path loss can be expressed as the ratio of power of transmitted signal to the power of the same signal received by the receiver on a given path. It is a function of the propagation distance.

Fading.

Fading mentions the fluctuations in strength of the signal when the signal is received at the receiver. Fading can be classified into two types –

- Fast fading/small scale fading and
- Slow fading/large scale fading

Interference.

Interference is the sum of all signal contributions that are neither noise not the wanted signal. Let's understand how its effect, its type and what possible source for it.

Doppler shift

The Doppler Effect is named after Austrian physicist Christian Doppler who proposed it in 1842. Doppler shift is referred as the change in frequency of a wave for an observer moving relative to the source of the wave. It is heard when a vehicle sounding a siren or horn approaches, passes, and recedes from an observer. The frequency is higher at the instant when it is emitted. The frequency is identical at the instant of passing by, and it is lower during the recession. For the waves that propagate in a medium like sound waves, where the velocity of the source and of the observer is corresponding to that of the medium in which the waves are transmitted. The total Doppler Effect may result from the motion of the observer, motion of the source, or motion of the medium.

3. Orthogonal Frequency Division Multiplexing (OFDM) is a multi-carrier modulation technique which is very much popular in new wireless networks of IEEE standard,

digital television, audio broadcasting and 4G mobile communications. LIST FIVE advantages and FIVE disadvantages.

Advantages of OFDM are listed as follows: **(10mks)**

• OFDM makes resourceful utilization of the spectrum by overlapping. By dividing the channel into narrowband flat fading sub channels, OFDM is more resistant to frequency selective fading than single carrier systems.
• It can easily adapt to severe channel conditions without complex time-domain equalization.
• Using sufficient channel coding and interleaving lost symbols can be recovered.
• Channel equalization becomes simpler than by using adaptive equalization techniques with single carrier systems.
• It is less sensitive to sample timing offsets than single carrier systems are.
• It is robust against narrow-band co-channel interference.
• Unlike conventional FDM (frequency division multiplexer), tuned sub-channel receiver filters are not required.
• It facilitates single frequency networks (SFNs); i.e., transmitter macro diversity.

The disadvantages are as follows: **(10mks)**

• The OFDM signal has a noise like amplitude with a very large dynamic range; hence it requires RF power amplifiers with a high peak to average power ratio.
• It is more sensitive to carrier frequency offset and drift than single carrier systems are due to leakage of the DFT.
• It is sensitive to Doppler shift.
• It requires linear transmitter circuitry, which suffers from poor power efficiency.
• It suffers loss of efficiency caused by cyclic prefix.

4. Integer linear formulation problem (20mks)

Merrill Lynch is considering investments into 6 projects: A, B, C, D, E and F. Each project has an initial cost, an expected profit rate (one year from now) expressed as a percentage of the initial cost,

and an associated risk of failure. These numbers are given in the table below:

	A	B	C	D	E	F
Initial cost (in M)	1.3	0.8	0.6	1.8	1.2	2.4
Profit rate	10%	20%	20%	10%	10%	10%
Failure risk	6%	4%	6%	5%	5%	4%

Provide a formulation to choose the projects that maximize total expected profit, such that Merrill Lynch does not invest more than 4M dollars and its average failure risk is not over 5%. For example, if Merrill Lynch invests only into A and B, it invests only 2.1M dollars and its average failure risk is (6%+4%)/2=5%.

Solution: Let $y_A = 1$ if project A is chosen, $y_A = 0$ otherwise. Define y_B, y_C, y_D, y_E, y_F similarly.

$$
\begin{aligned}
&Max \quad 0.13y_A + 0.16y_B + 0.12y_C + 0.18y_D + 0.12y_E + 0.24y_F \\
&St \\
&1.3y_A + 0.8y_B + 0.6y_C + 1.8y_D + 1.2y_E + 2.4y_F \leq 4 \\
&0.06y_A + 0.04y_B + 0.06y_C + 0.05y_D + 0.05y_E + 0.04y_F \leq 0.05(y_A + y_B + y_C + y_D + y_E + y_F) \\
&y_A, y_B, y_C, y_D, y_E, y_F \in \{0, 1\}.
\end{aligned}
$$

5. Interference is one of the characteristics of wireless communication channels. Discuss this further (from question 2 above) stating the <u>effects</u> of interference, the <u>sources</u> of interference and expanding the two given <u>types</u> of interference below (20mks)

<u>Interference.</u>

Interference is the sum of all signal contributions that are neither noise not the wanted signal. Let's understand how its effect, its type and what possible source for it.

<u>Effects of Interference.</u>

- Interference is an important limiting factor in the performance of cellular systems.
- Interference degrades the quality of the signal.
- It initiates bit errors in the received signal.
- Bit errors are partly recoverable by means of the channel coding and the error correction mechanisms.
- The situation of the interference is not reciprocal to the uplink and downlink direction.
- Mobile stations and base stations are introduced to different interference situation.

<u>Sources of Interference</u>

- When another mobile is present in the same cell.

- When a call is in progress in the neighbouring cell.
- When other base stations are operating on the same frequency.
- When any non-cellular system leaks energy into the cellular frequency band.

Types of Interference

There are two types of system generated interference

1. Co-channel interference

2. Adjacent channel interference

Co-Channel Interference

- Co-channel interference occurs the because of frequency reuse, i.e., several cells use the same set of frequency.
- These cells are called co-channel cells.
- Co-channel interference cannot be combated by increasing the power of the transmitter. This is because an increase in carrier transmit power increases the interference to neighbouring cochannel cells.
- To reduce the co-channel interference, the cells must be separated by a minimum distance to provide sufficient isolation due to propagation or reduce the footprint of the cell.
- Some factors other than reuse distance that influence co-channel interference are antenna type, directionality, height, site position etc.

Adjacent channel interference

- Interference concluding from the signals which are adjacent in frequency to the desired signal is called adjacent channel interference.
- Adjacent channel interference results from imperfect receiver filters which allow nearby frequencies to leak into the pass band.
- Adjacent channel interference can be minimized through channel assignments and careful filtering.
- By keeping the frequency separation between each channel in a given cell as large as possible, the adjacent interference may be reduced considerably.