Prob.1:

Ans. a. We have $C = B \log_2 (1 + SNR)$. For SNR = 0.1, C = 0.41 MHz; For SNR = 0.01, C = 3.9 MHz; for SNR = 0.001, C = 38.84 MHz. Thus, to achieve the desired SNR, the signal must be spread so that 56 KHz is carried in very large bandwidths.

b. For 1 bps/Hz, the equation $C = B \log_2 (1 + SNR)$ becomes $\log_2 (1 + SNR) = 1$. Solving for SNR, we have SNR = 1.

Thus a far higher SNR is required without spread spectrum.

Prob. 2:

Ans.

1000 users/cell
User registration every 3 minutes
Call origination: 3 calls/hour
Call termination: 3 calls/hour

Event Name	# Events /hour	Operation	Direction	Channel
User registration	1000 * 20 = 20k	Request	MS -> BS	RACH
		Response	BS -> MS	PAGCH
Call origination	1000 * 3 = 3k	Request	MS -> BS	RACH
		Response	BS -> MS	PAGCH
Call termination	1000 * 3 = 3k	Paging	BS -> MS	PAGCH
		Request	MS -> BS	RACH
		Response	BS -> MS	PAGCH

Number of slots required / second
RACH = (20k + 3k + 3k) / 3600 = 7.22
PAGCH = (20k + 3k + 3k*2) /3600 = 8.06

Number of slots provided by GSM / second (Lecture 3)
RACH = 1/4.615m = 216.68
PAGCH = (1/4.615m) * (36/51) = 152.95

Therefore, channel utilization:
U_{RACH} = 7.22/ 216.68 = 3.33%
U_{PAGCH} = 8.06/ 152.95 = 5.27%

Note that, since slotted aloha protocols is used for reverse channel and paging delay in the forward channel has to be kept low, low utilization values are essential

Prob. 3

Ans. (a):

Handoff call arrival rate:

λ_1 = 24 calls/h = 0.00667 calls/s

New call arrival rate:

λ_2 = 120 calls/h = 0.0333 calls/s

Total arrival rate:

$\lambda = \lambda_1 + \lambda_2 = 0.04$ calls/s

Service rate:

μ = 1/(call holding time) = 1/100 = 0.01 calls/s

Offered load:

A = (Total arrival rate) / (Service rate) = 4

Number of channels:

N = 8

The new calls and handoff calls have the same blocking probability as obtained by Erlang B formula with A = 4 and N = 8 (Lecture 2).

$P_b = 3.04\%$

Ans. (b)

Refer to Figure (b) Single cell with new and handoff calls and 1 guard channel.

List the balance equations:

$i\mu P_i = (\lambda_1+\lambda_2)P_{i-1}$ (for $0 < i < 8$)
$8\mu P_8 = \lambda_1 P_9$

Let $\rho = (\lambda_1+\lambda_2)/\mu$
Solve $\Sigma P_i = 1$ to obtain P_0.

Handoff call blocking probability:

$P_8 = (\lambda_1\rho^7 P_0) / (\mu\, 8!) = 0.52\%$

New call blocking probability:

$P_7+P_8 = (\rho^7 P_0) / (7!) + (\lambda_1\rho^7 P_0) / (\mu\, 8!) = 6.24\% + 0.52\% = 6.76\%$

Thus, handoff call blocking probability is significantly reduced (from 3% to 0.5%) at the expense of increase in new call blocking probability (from 3% to 6.8%)

Prob. 4

Ans. (a)

Total number of users = 30,000 *250 = 7.5 million
Total number of effective users = 0.2 * 7.5M + 0.3 * 7.5M * 2 + 0.5 * 7.5M *3 = 17.25M
Number of regions = $30{,}000/(50/4)^2$ = 192
Average number of effective users/region = 17.25M/192=89843.75
Number of pages/second = 89843.75 * 1.6/3600 = 39.93 pages/sec

Ans. (b)

Average number of users /region = 7.5M/192 = 39062.5
Number of pages/sec = 39062.5 * 1.6/3600 = 17.36 pages/sec
Number of Registrations (acks)/second = 250*10*50/(3.14*3600) = 11.06 acks/sec
Total downlink messages/second = 17.36+11.06 = 28.42 messages/second

Clearly, adding registrations to this system proved beneficial as it resulted in the reduction of number of downlink messages/second.