CHAPTER 9

9.1 (a) raw data rate provided for each user

$= \frac{270.833}{8} \doteq \underline{\underline{33.85 \text{ kbps}}}$

(b) traffic efficiency for each user

$= (1 - \frac{10.1}{33.85}) \times 100\% \doteq \underline{\underline{70\%}}$

9.2 raw data rate provided for each user $= \frac{48.6}{3} = \underline{\underline{16.2 \text{ kbps}}}$

9.3 (a) A frame has $6 \times 324 = 1944$ bits.

The number of overhead bits per frame is given by

$b_{OH} = 6\times6 + 6\times6 + 6\times28 + 6\times12 + 6\times12 = 384$ bits

$\Rightarrow$ frame efficiency $\eta_f = [1 - \frac{384}{1944}] \times 100\% \doteq \underline{\underline{80.2\%}}$

(b) For half rate speech coding.

raw data rate provided for each user $= \frac{48.6}{6} = \underline{\underline{8.1 \text{ kbps}}}$

As shown in (a), frame efficiency $\eta_f = \underline{\underline{80.2\%}}$

9.4 (a) raw data rate provided for each user

$= \frac{42.0}{3} = \underline{\underline{14 \text{ kbps}}}$

(b) number of bit per frame

$=$ frame duration $\times$ data rate $= 6.667 \times 10^{-3} \times 42.0 \times 10^{3}$

$= 280$ bits/frame

$\boxed{9.7}$ (a) packet duration, $\tau = \frac{1000}{10 \times 10^6} = 10^{-4}$ s

$\Rightarrow$ traffic occupancy, $R = \lambda \cdot \tau = 10^3 \times 10^{-4} = 0.1$ Erlangs.

$\Rightarrow$ The normalized throughput of the system,

$$T = R \cdot e^{-2R} = 0.1 \times e^{-2 \times 0.1} \doteq \underline{\underline{0.082}}$$

(b) For unslotted ALOHA, when $R = \frac{1}{2}$, the throughput will be maximized, therefore:

$$\tau = \frac{R}{\lambda} = \frac{\frac{1}{2}}{10^3} = 5 \times 10^{-4} \text{ s}$$

$\Rightarrow$ number of bits per packet $= \tau \cdot$ bit rate

$$= 5 \times 10^{-4} \times 10 \times 10^6 = \underline{\underline{5 \times 10^3 \text{ bits}}}$$

$\boxed{9.8}$ (a) For slotted ALOHA,

$$T = R \cdot e^{-R} = 0.1 \times e^{-0.1} \doteq \underline{\underline{0.09}}$$

(b) For slotted ALOHA, when $R = 1$, the throughput will be maximized. Therefore, $\tau = \frac{R}{\lambda} = \frac{1}{10^3} = 10^{-3}$ s.

$\Rightarrow$ number of bits per packet $= \tau \cdot$ bit rate

$$= 10^{-3} \times 10 \times 10^6 = \underline{\underline{10^4 \text{ bits}}}$$

$\boxed{9.9}$ Propagation time $t_p = \frac{d}{c} = \frac{10 \times 10^3}{3 \times 10^8} \doteq 3.33 \times 10^{-5}$ s.

$\Rightarrow$ propagation delay $t_d = \frac{t_p \cdot R_b}{m} = \frac{3.33 \times 10^{-5} \times 19.2 \times 10^3}{256}$

$= \underline{\underline{0.0025 \text{ packet transmission units}}}$

9.9 Cont'd

For slotted ALOHA, when $R=1$, the throughput will be maximized.

Therefore, $\tau_{optimum}$ should satisfy the condition $\lambda \cdot \tau_{optimum} = 1$

$\Rightarrow \tau_{optimum} = \frac{1}{\lambda}$. In this case the data rate $= 19.2$ Kbps,

$\Rightarrow$ bit period $= \frac{1}{19.2\,Kbps} \doteq 52.08\,\mu s$

$\Rightarrow \tau = 256$ bits/packet $\times 52.08\,\mu s$/bit $= \underline{\underline{13.33\,ms}}$

$\Rightarrow \lambda = \frac{R}{\tau} = \underline{\underline{75 \text{ packets/second}}}$.

$\boxed{9.10}$ For $n=3$, $\left(\frac{C}{I}\right)_{min} = 14\,dB \doteq 25.12$, we have the co-channel reuse factor, $Q \geq \left(6\left(\frac{C}{I}\right)_{min}\right)^{\frac{1}{n}}$

$\Rightarrow \sqrt{3N} \geq (6 \times 25.12)^{\frac{1}{3}} \doteq 5.32 \Rightarrow N \geq 9.43$

$\Rightarrow N = 12$

$\Rightarrow$ number of analog channels per cell,

$$m = \frac{B_t}{B_c \cdot N} = \frac{20 \times 10^6}{30 \times 10^3 \times 12} \doteq \underline{\underline{55 \text{ channels/cell}}}$$

$\boxed{9.11}$ $\underline{\text{For } n=2}$, we need $Q \geq \left(6\left(\frac{C}{I}\right)_{min}\right)^{\frac{1}{2}} = (6 \times 25.12)^{\frac{1}{2}}$
$\doteq 12.28$

$\Rightarrow N \geq \frac{Q^2}{3} = \frac{12.28^2}{3} = 50.24 \Rightarrow N = 6^2 + 2^2 + 6 \times 2 = 52$

$$\Rightarrow m = \frac{B_T}{B_c \cdot N} = \frac{20 \times 10^6}{30 \times 10^3 \times 52} \doteq \underline{\underline{13 \text{ channels/cell}}}$$

9.11 Cont'd

For $n=4$, we need $Q \geq (6\times 25.12)^{\frac{1}{4}} \doteq 3.5$

$\Rightarrow N \geq \frac{Q^2}{3} \doteq 4.09 \Rightarrow N=7$

$$\Rightarrow m = \frac{B_T}{B_c \cdot N} = \frac{20\times10^6}{30\times10^3\times7} \doteq \underline{\underline{95 \text{ channels/cell}}}$$

$\boxed{9.12}$ $\frac{E_b}{N_o} = \frac{W/R}{N-1}$

$$\Rightarrow W = \frac{E_b}{N_o}\cdot(N-1)\cdot R = 100\times(100-1)\times13\times10^3$$

$$= 1.287\times10^8 \text{ chips/sec} = \underline{\underline{128.7 \text{ M chips/sec}}}$$

$\boxed{9.13}$ For $\alpha=0.4$, $\frac{E_b}{N_o} = \frac{W/R}{(N-1)\alpha}$

$$\Rightarrow W = \frac{E_b}{N_o}\cdot(N-1)\cdot\alpha\cdot R = 1.287\times10^8\times0.4$$

$$\doteq \underline{\underline{51.46 \text{ M chips/sec}}}$$

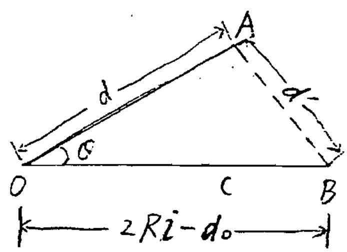
$\boxed{9.14}$ For tri-sectored CDMA system with voice activity $\alpha=0.4$, $\frac{E_b}{N_o} = \frac{W/R}{(\frac{N}{3}-1)\cdot\alpha}$

$$\Rightarrow W = \frac{E_b}{N_o}\cdot\left(\frac{N}{3}-1\right)\cdot\alpha\cdot R = 100\times\left(\frac{100}{3}-1\right)\times0.4\times13\times10^3$$

$$\doteq \underline{\underline{16.8 \text{ M chips/sec}}}$$

$\boxed{9.15}$ For $(2i-1)\cdot R \leq d \leq (2i)R-d_o$, from the figure left, we have

$$|BC| = |OB| - |OC|$$
$$= 2Ri - d_o - d\cos\theta$$



$(2i-1)R \leq d \leq (2i)\cdot R-d_o$

9.17 For a single cell CDMA system, $P_b = Q\left(\sqrt{\frac{3DN}{K-1}}\right)$.

$\Rightarrow \sqrt{\frac{3DN}{K-1}} = Q^{-1}(P_b)$. where $Q^{-1}(\cdot)$ is the inverse function of Q function

$$\Rightarrow K = \frac{3DN}{[Q^{-1}(P_b)]^2} + 1$$

Given $D = 10\,dB = 10$, $P_b = 10^{-3}$, $N = 511$, we have

$$K = \frac{3\times10\times511}{[Q^{-1}(10^{-3})]^2} + 1 \doteq \frac{3\times10\times511}{(3.1)^2} + 1 \doteq \underline{\underline{1596 \text{ users}}}$$

In actuality, only 511 users would likely be used in a single cell to ensure low cross-correlation between users.

9.18 In this case $P_b = Q\left(\sqrt{\frac{3DN}{(K-1)\cdot\alpha}}\right)$, where $\alpha = 0.4$ is the voice activity factor. Similarly, we have

$$K = \frac{3DN}{\alpha[Q^{-1}(P_b)]^2} + 1 = \frac{3\times10\times511}{0.4\times(3.1)^2} + 1 \doteq \underline{\underline{3989 \text{ users}}}$$

9.19 The frequency reuse factor f for reverse channel of CDMA cellular system, as a function of n, can be found from Table 9.4.

Assume the users are uniformly distributed, for $n = 2$, from table 9.4, we get $f \doteq 0.46$. Given $D = 6\,dB = 4$, $N = 511$, we have

$$K = \frac{3f\cdot DN}{[Q^{-1}(P_b)]^2} + 1 = \frac{3\times0.46\times4\times511}{[Q^{-1}(0.01)]^2} + 1 \doteq \underline{\underline{520 \text{ users}}}$$

9.19 Cont'd

For $n=3$, $f \doteq 0.6$, $\Rightarrow K = \frac{3\times0.6\times4\times511}{2.33^2} + 1 \doteq \underline{\underline{678 \text{ users}}}$

For $n=4$, $f \doteq 0.7$, $\Rightarrow K = \frac{3\times0.7\times4\times511}{2.33^2} + 1 \doteq \underline{\underline{791 \text{ users}}}$

$\boxed{9.20}$ Using the concentric cellular geometry, for the ith surrounding layer, the inner and outer sectors of each cell have areas given by

$$A_{in}/M_i = \left\{\pi(2iR)^2 - \pi[(2i-1)R]^2\right\}/8i$$
$$= \frac{4i-1}{8i}\cdot\pi R^2 = \frac{4i-1}{8i}\cdot A$$

$$A_{iout}/M_i = \left\{\pi[(2i+1)\cdot R]^2 - \pi\cdot(2iR)^2\right\}/8i$$
$$= \frac{4i+1}{8i}\cdot\pi R^2 = \frac{4i+1}{8i}\cdot A$$

Applying the weighting factors for the user density within the inner (W_{in}) and outer (W_{iout}) sectors in the ith surrounding layer, we have.

$$U = KA = K\cdot\left[\frac{4i-1}{8i}\cdot W_{in}\cdot A + \frac{4i+1}{8i}W_{iout}\cdot A\right].$$

For the equivalent hexagonal geometry, we have

$$\begin{cases} \frac{4i-1}{8i}\cdot W_{in} = \frac{1}{2} \\ \frac{4i+1}{8i}\cdot W_{iout} = \frac{1}{2} \end{cases} \Longrightarrow \underline{\underline{\begin{cases} W_{in} = \frac{4i}{4i-1} \\ W_{iout} = \frac{4i}{4i+1} \end{cases} \quad i=1,2,\cdots}}$$

For $i=2$, $W_{in} = \underline{\underline{\frac{8}{7}}}$, $W_{iout} = \underline{\underline{\frac{8}{9}}}$