Problem 1

1. Consider the following system made up of 150 MSC/VLRs. Each user receives 3 calls/hour, there are 320 users/sq. mile, users move at an average speed of 8 miles/hr. Each HLR in this system can support 25,000 users, and MSC covers a square region with perimeter of 30 miles. If HLRs can process 100 incoming operations/second maximum and VLR/MSCs can process 40 incoming operations/second, determine the delay to locate a user during incoming calls. Ignore authentication and ciphering procedures and also assume SS7 and paging delays are negligible. Operations only include messages requesting an action, not responses. Determine the delay, assuming that a) subscriber information is downloaded to the VLR during call establishment and b) subscriber information is downloaded to the VLR during registration (50 pts).

Solution

 # MSC/VLR = 150

λ = 3 incoming calls/hour

n = 320 users/sq. mile

v = 8 miles/hour

L = 30 miles

HLR: 100 incoming operations/second maximum

VLR/MSC = 40 incoming operations/second maximum

Ignore: authentication, ciphering, SS7 and paging delays.

Operations only include messages requesting an action, not responses.

Solution

Assuming M/M/1 model:

Avg Delay T = $\rho/((1-\rho)*\lambda) = 1/(\mu-\lambda)$**,**

where λ **is arrival rate,** μ **is service rate**

We have μ_{HLR} **= 100/sec,** μ_{VLR} **= 40/sec; need to calculate arrival rate at the HLR and the VLR**

Boundary crossing rate = nvl/π **= 6.8 crossings/second**

Each MSC/VLR serves users 18,000 users.

Each HLR serves 25,000 users.

Solution

a) Subscriber information is downloaded during call to the VLR

a.1) Delay at VLR

- **Load on VLR due to mobility (Update Location Area and Registration Cancellation) = 6.8*2 = 13.6 operations/second.**
- **Load on VLR due to new incoming calls (provide roaming # query) = 3*18,000 / 3,600 = 15 operations/second**
- **Arrival rate = Total operations/second = 13.6+15 = 28.6/sec**
- **Service rate = 40/sec**
- **Avg. Delay at VLR = 1/(40-28.6) = 88ms**

Solution

a) Subscriber information is downloaded during call to the VLR

a.2) Delay at HLR

- Load on HLR due to mobility (Update Location Area) = 6.8*25000/18000 = 9.4 operations/second.
- Load on HLR due to new incoming calls (provide roaming # and Send Subscriber info) = 2*3*25,000 / 3,600 = 41.7 operations/second
- Arrival rate = Total operations/second = 9.4+41.7 = 51.1/sec
- Service rate = 100/sec
- Avg. Delay at HLR = 1/(100-51.1) = 20ms

Solution

a) **Subscriber information is downloaded during call to the VLR**

a.3) Delay for incoming call

- **HLR needs to complete two operations (provide roaming # and send subscriber info)**
- **VLR needs to complete one operation (provide roaming #)**
- **Total avg. delay = 2*(avg. delay/operation at HLR) + 1*(avg.delay/operation at VLR) = 2*20 + 88 = 128ms.**

Solution

b) Subscriber information is downloaded during reg. to the VLR

b.1) Delay at VLR

- **Load on VLR due to mobility (Update Location Area, Insert subscriber data, and Registration Cancellation) = 6.8*3 = 20.4 operations/second.**
- **Load on VLR due to new incoming calls (provide roaming # query) = 3*18,000 / 3,600 = 15 operations/second**
- **Arrival rate = Total operations/second = 20.4+15 = 35.4/sec**
- **Service rate = 40/sec**
- **Avg. Delay at VLR = 1/(40-35.4) = 217ms**

Solution

b) Subscriber information is downloaded during reg. to the VLR

b.2) Delay at HLR

- **Load on HLR due to mobility (Update Location Area) = 6.8*18000/25000 = 9.4 operations/second.**
- **Load on HLR due to new incoming calls (provide roaming #) = 3*25,000 / 3,600 = 20.8 operations/second**
- **Arrival rate = Total operations/second = 9.4+20.8 = 30.2/sec**
- **Service rate = 100/sec**
- **Avg. Delay at HLR = 1/(100-30.2) = 14ms**

Solution

b) Subscriber information is downloaded during reg. to the VLR

b.3) Delay for incoming call

- **HLR needs to complete one operation (provide roaming #)**
- **VLR needs to complete one operation (provide roaming #)**
- **Total avg. delay = 1*(avg. delay/operation at HLR) + 1*(avg.delay/operation at VLR) = 14 + 217 = 231ms.**

=> Caching subscriber information at the VLR is NOT beneficial for reducing incoming call delays as VLR gets overloaded with downloading subscriber information during each move.

Problem 2

2. Consider a CDMA system in which users A and B have Walsh codes (-1 1 –1 1 –1 1 –1 1) and (-1 –1 1 1 –1 –1 1 1) respectively. Show a) output at receiver of A if A transmits bit ‘1’ and B does not transmit; b) output at receiver of A if A transmits bit ‘0’ and B does not transmit; c) output at receiver of A if A and B both transmit a ‘1’ bit assuming received power from both A and B are same; d) output at receiver of A if A transmits bit ‘0’ and B transmits bit ‘1’ assuming same received power; and e) output at receiver of A if A and B transmit bit ‘1’ assuming received power from B is twice received power from A - this can be represented by showing received signal from A has magnitude 1 (+1,-1) and received signal from B has magnitude 2 (+2,-2). (20 pts).

Solution

a. 8

b. –8

c. 8

d. –8

e. 8

A: 1	-1	1	-1	1	-1	1	-1	1	
B: 1	-2	-2	2	2	-2	-2	2	2	
Recd.	-3	-1	1	3	-3	-1	1	3	
A's code	-1	1	-1	1	-1	1	-1	1	
Mult.	3	-1	-1	3	3	-1	-1	3	=8

Problem 3

3. **Determine the maximum number of 9.6Kbps calls that can be supported in a single-cell IS-95 based CDMA system if the minimum Eb/No required is 6dB for a) omni-directional base station with no voice activity detection, b) omni-directional base station with voice activity detection ratio of 40% and c) three-sectored base station with sector gain factor of 2.4 and voice activity detection ratio of 40%. Assume perfect power control. (20 pts).**

Solution

Eb/No = 6dB = 4;

W/R = 1.2288 * 10^6/9600 = 128

a) *N ~ (W/R)/(Eb/No) = 32 calls/cell*

b) $F_{speech} = 1/0.4 = 2.5$;

N ~ $(W/R)F_{speech}/(Eb/No)$ *= 80 calls/cell*

(Walsh code availability would limit this to <= 64)

c) $F_{sector} = 2.4$; $F_{speech} = 2.5$;

N ~ $(W/R)F_{speech}F_{sector}/(Eb/No)$ *= 192 calls/cell*