ECEN4533 Design Problem #1 70 points Due 5:00PM, ?? February

You are a Staff Engineer, Networking, for MegaMoron Communications Inc., the world's premier communications design company. You have been tasked with the design of a Voice over Internet Protocol (VoIP) backbone for RedNeckNet, a start up regional Internet Service Provider (ISP).

RedNeckNet is installing telephone gateways in Stillwater, Oklahoma; Joplin, Missouri; Lubbock and Dallas, Texas; Little Rock, Arkansas; and Salina, Kansas. At the gateways, digital audio received from telephone networks will be converted to packets, shipped over the to-be-constructed VoIP backbone to a destination gateway, and then converted back to digital telephone network format.

The president of the company, a Mr. H. Simsen, has insisted that the VoIP WAN backbone be a Leased Line network hauled by the carrier he has the most stock in, U.S. Sprawl. Given this constraint, your goal is to **design a least cost network that will meet maximum one-way end-to-end delay specifications during the peak traffic period.**

Investigation has revealed the following:

* Besides terminating and originating audio traffic, the gateways will also act as intermediate routers, forwarding traffic destined for other Gateways.

* The design specifications call for no redundancy, hence a single trunk to each Gateway location is allowable.

* Each audio stream will be converted to a variable rate bit stream at the originating Gateway. The compression algorithm selected for use generates an average of 8 Kbps per voice stream, i.e. each simplex voice call generates 10 Kbps of *Application Traffic.*

* The application traffic must be inserted into fixed length packets. *You must specify the packet size*.

* The overhead associated with each packet is 47 bytes (7 bytes Point-to-Point Protocol, 20 bytes IPv4, 8 bytes User Datagram Protocol, and 12 bytes Real Time Transport Protocol).

* A proprietary Layer 2 protocol will be used on the backbone. The protocol can handle average packet sizes ranging from 48 B to 2.2 KB, in one byte increments. The choice of voice packet size will impact the total traffic that must be moved.

Example A) If you choose a packet size of 100 bytes per packet, 53 bytes/packet (424 bits/packet) will be available to move the application voice traffic. This will result in an average of 10,000/424 = 23.58 packets/second per simplex voice call. Including overhead, an average of 23.58 pps*100 B/packet *8 bits/B = 18,864 bps must therefore be moved for each call.

Example B) If you choose a packet size of 200 bytes per packet, 153 bytes/packet (1224 bits/packet) will be available to move the application voice traffic. This will result in an average of 10,000/1224 = 8.170 packets/second per simplex voice call. Including overhead, an average of 8.170*200*8 = 13,072 bps must therefore be moved for each simplex voice call.

* *CodingDelay* = (voice bits placed in each packet)/10 Kbps

Example) A 100 byte packet, with 424 application bits in each packet, has a *CodingDelay* = 42.4 msec.

Example) A 200 byte packet, with 1224 application bits in each packet, has a *CodingDelay*= 122.4 msec.

* The propagation delays between sites are as follows:

Stillwater - Lubbock: 5.2 msec
Stillwater - Joplin: 2.5 msec

Stillwater - Salina: 3.0 msec
Stillwater - Dallas: 3.7 msec
Stillwater - Little Rock: 4.6 msec
Joplin - Lubbock: 7.8 msec
Joplin - Salina: 3.4 msec
Joplin - Dallas: 5.2 msec
Joplin - Little Rock: 3.3 msec
Lubbock - Salina: 7.0 msec
Lubbock - Dallas: 4.8 msec
Lubbock - Little Rock: 8.9 msec
Dallas - Little Rock: 4.6 msec
Dallas - Salina: 6.7 msec
Salina - Little Rock: 6.5 msec

* With 99.99% probability, the voice signals between *each* City Pair must spend $\leq$ 260 msec in the RedNeckNet VoIP network. Call this the *EndtoEndDeliveryDelay*.

* Lab tests have shown that, with 99.99% probability, the maximum time spent in a gateway/router can be written as

RouterDelay = 9*Packet Size (bits)/[Trunk Line Speed (bps) - Average Traffic Carried (bps)].

Example) If the voice packet size is 200 bytes, a packet traversing a 1.2 Mbps trunk from Salina to Little Rock carrying a total of 771,248 bps (59 phone calls) would, with 99.99% probability, spend a maximum of *RouterDelay* = 9*1600/(1.2 Mbps - 771.2 Kbps) = 33.59 msec in the Salina gateway/router.

* For the purposes of this project, the *EndtoEndDeliveryDelay* can be written as the sum of the *CodingDelay*, the sum of the *PropagationDelays* of the links the signal traverses, and the sum of the *RouterDelays* seen at the RedneckNet trunks a call must traverse. The system must be engineered so that the delivery delay bound is met between each City Pair.

Example) If calls between Stillwater and Lubbock are routed through Salina, the *EndtoEndDeliveryDelay* equation would include one *CodingDelay*, *PropagationDelays* of 3.0 + 7.0 = 10.0 msec, and two *RouterDelays*, one for the delay seen entering the Stillwater to Salina trunk, and one for the delay seen entering the Salina to Lubbock trunk.

Example) Traffic originating at Stillwater and terminating at Lubbock would have one *QueueingDelay, PropagationDelay,* and *RouterDelay* term if a direct connection existed between Stillwater and Lubbock.

* Leased Lines from U.S. Sprawl are available from 1 Kbps on up, in 1 Kbps increments.

* Leased Line pricing is a function of distance and bandwidth. Use the following formula to calculate monthly costs for *each* Leased Line in place:

$$\text{Monthly Leased Line Costs} = \$237 + \$164(\text{propagation delay in msec})^{0.80}[(\text{trunk line speed})/(1.70\text{ Mbps})]^{0.34}$$

Example) An 86 Kbps Leased Line between Dallas and Little Rock would cost $\$237 + \$164(4.6)^{0.80}[.05059]^{0.34} = \$237 + \$164(3.390)(.3626) = \$438.57$ per month.

These are full duplex lines, so you get the listed bandwidth in both directions. For example, a 86 Kbps leased line between Dallas and Tulsa gives you 86 Kbps from Dallas to Tulsa *and 86* Kbps from Tulsa to Dallas.

* Plug-in Router cards are required at each Router-Gateway for each terminated trunk. Monthly cost per card is $97 + $.029*(Line Speed in Kbps).

Example) If the Stillwater Gateway will terminate two 903 Kbps and one 2.150 Mbps trunks, the monthly cost for the three plug-in router cards is 3*$97 + $.029*3956 = $405.72.

* The following *traffic matrix* shows the expected number of simplex voice calls that must be connected between sites, during the peak traffic period. Networks should be sized to handle this traffic flow.

From \ To	*Dallas*	*Little Rock*	*Lubbock*	*Stillwater*	*Joplin*	*Salina*
Dallas	-	179	27	65	23	102
Little Rock	179	-	106	87	75	136
Lubbock	27	106	-	48	11	64
Stillwater	65	87	48	-	28	59
Joplin	23	75	11	28	-	31
Salina	102	136	64	59	31	-

Rules of Engagement:

You may work alone or in two person teams.

Treat your project as if it were proprietary corporate information, i.e. do not disseminate your design in any manner to the competition. Doing so, and getting caught, will get anyone "fired" (i.e. an F for the course).

Make your final report short and sweet. *DO NOT GIVE ME A RUNNING COMMENTARY OF YOUR DERIVATION*. I will dock you points if you do so. Your final report should be about three to four pages and include:

(1) *A WAN backbone network diagram* showing trunk locations, average traffic (including overhead) routed over these trunks, and trunk size.

(2) *A table*, with 15 entries, showing how calls between each City Pair entry are routed, and the expected maximum one-way end-to-end delivery delays traffic will face moving over this route. NOTE: If you use asymmetrical routing (different paths in different directions) your table in (2) will need to be doubled in size, and your diagram in (1) should clearly indicate the average amount of traffic routed in each direction.

(3) A list of costs (links & router cards).

(4) Sample calculations for *EndtoEndDeliveryDelay* (pick one city pair and show all calculations for that connection).

The low bid will be that design with the lowest monthly cost. The low bid designer(s) will receive 20 extra credit points. The 2nd lowest bid designer(s) will receive 15 points, and the 3rd lowest bid designer(s) will receive 10 points. All remaining designs with cost < the average class cost will receive 5 points extra credit. Only *working* bids will be considered for the above. The instructor reserves the right to modify these rules in the event of a tie, and to deduct points for crappy designs.

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