UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 7 Examination in Engineering: October 2019

Module Number: EE7208   Module Name: Advanced Data Communication

[Three Hours]

[Answer **all questions**, each question carries 10 marks]

Erlang B entries are given in Table 1.

Q1 a) i)   State two types of packet switching connections and briefly explain one of them.

   ii) Explain the technologies Carrier Sense Multiple Access with Collision Detection (CSMA/CD) and Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA), stating the difference between them.

[3.0 Marks]

   b) i)   State the benefits of Asynchronous Transfer Mode (ATM) compared to Time Division Multiplexing (TDM) in terms of transmission efficiency.

   ii) Explain the switching operation of ATM.

[3.0 Marks]

   c) i)   Explain the requirement of Multi-Protocol Labelled Switching (MPLS) technology stating the drawbacks of conventional Internet Protocol (IP) networks.

   ii) What is the function of Label Forwarding Information Base (LFIB) in MPLS operation?

   iii) List the steps of MPLS operation.

[4.0 Marks]

Q2 a) Explain the difference between the two performance measures, call congestion and time congestion in lost call cleared systems.

[1.5 Marks]

   b) An exchange is designed to handle 2000 calls during the busy hour. One day, the number of calls during the busy hour is 2200. What is the Grade-of-Service (GoS) of the exchange?

[2.5 Marks]

c) There are two types of call arrivals for a mobile network, new calls that originate in the cell and calls that are handed over from neighbouring cells. It is desirable to give preference for handover calls over new calls. For this reason, certain number of channels are reserved for handover calls and the remaining channels are available to both types of calls. Assume the following measures of the mobile network.

- Channels in the cell are held for two minutes on average with an exponential distribution.
- All calls arrive according to a Poisson process with the rates, $\lambda_{NC} = 125$ calls per hour for new calls and $\lambda_{HC} = 50$ calls per hour for handover calls.
- The cell has a capacity of 10 channels and each call occupies one channel.

i) Draw a state transition diagram of the channel occupancy in a cell when two channels are used only for handover calls.

ii) Calculate the blocking probability of the cell, if no channels are reserved for handover calls.

iii) Determine the minimum number of channels reserved for handover calls thus their blocking probability is below 1%?

iv) What is the blocking probability for the new calls of part iii)?

[6.0 Marks]

Q3 a) Using the state transition diagrams, show the difference between a lost calls cleared (LCC) system and a lost calls held (LCH) system.

[3.0 Marks]

b) A company has a centralized call center with n parallel lines phone lines. In addition, there is one holding line $(m = 1)$ for a call that is waiting to get a service when all n servers are busy. If in such a situation, the holding line is also occupied, the call is blocked and thus lost. Assume that the customers generate calls according to a Poisson process with an arrival intensity of λ. Moreover, the call holding times are independent and identically distributed following the $\exp(\mu)$ distribution.

i) Denoting by $X(t)$ the number of customers in the system, that is, customers getting service and possibly one customer waiting and $X(t)$ is a Markov process, draw its state transition diagram.

ii) Assume $n = 2$, $\lambda = \dfrac{1}{3}$ calls per minute and $\mu = \dfrac{1}{3}$ calls per minute. Derive the steady state distribution of the system.

iii) Calculate the probability that a customer is held on the holding line.

[7.0 Marks]

Q4 a) i) Define the uniquely decodable property of variable length codes.

      ii) Give an example to show the importance of having the uniquely decodable property for a discrete source.

[2.0 Marks]

b) Three variable length codes are shown in Table Q4.

Table Q4

Letter	$P\left(a_k\right)$	Code-I	Code-II	Code-III
a_1	1/2	1	0	0
a_2	1/4	00	10	01
a_3	1/8	01	110	011
a_4	1/8	10	111	111

      i) Check whether the codes given in Table Q4 are uniquely decodable or not.

      ii) Which uniquely decodable code is a prefix-free code? How do you verify this?

[4.0 Marks]

c) Consider a random variable X which takes on probabilities $\left\{\frac{1}{3}, \frac{1}{3}, \frac{1}{4}, \frac{1}{12}\right\}$. Construct a Huffman code for the random variable X.

[4.0 Marks]

Q5 a) Explain the difference between source coding and channel coding in telecommunication networks.

[1.0 Mark]

b) It is required to transmit the ASCII letter " J ", which in binary form of 1001010 and then be able to check for errors using CRC - 8 code. Take the CRC - 8 generator polynomial as 100000111. Determine the transmitted sequence.

[3.0 Marks]

c) i) $\left(\frac{1}{2}\right)$ rate convolutional encoder is defined by two generator polynomials $P_0[n] = x[n] + x[n-1] + x[n-2]$ and $P_1[n] = x[n] + x[n-2]$. Assume that data is fed into the shift register one bit at a time.

        I) Draw the state transition diagram of this code. The states should be labeled with the binary string $x[n-1]$ .... $x[n-k+1]$ and the arcs labeled with $x[n]/p_0 p_1$ where $x[n]$ is the next message bit and p_0 and p_1 are the two parity bits computed from $p_0[n]$ and $p_1[n]$ respectively.

        II) Draw the trellis diagram for this code.

      ii) Use the Viterbi decoding algorithm to decode the received block of data 10 00 10 00. Show the decoded path on a single trellis diagram.

[6.0 Marks]

Table 1: Erlang B Traffic for Lost Calls Systems

Trunks	0.05	0.02	0.01	0.005	0.002	0.001
	E	E	E	E	E	E
1	0.053	0.020	0.010	0.005	0.002	0.001
2	0.381	0.223	0.153	0.105	0.065	0.046
3	0.899	0.602	0.455	0.349	0.249	0.194
4	1.525	1.092	0.869	0.701	0.535	0.439
5	2.218	1.657	1.361	1.132	0.900	0.762
6	2.960	2.276	1.909	1.622	1.325	1.146
7	3.738	2.935	2.501	2.157	1.798	1.579
8	4.543	3.627	3.128	2.730	2.311	2.051
9	5.370	4.345	3.783	3.333	2.855	2.557
10	6.216	5.084	4.461	3.961	3.427	3.092
11	7.076	5.842	5.160	4.610	4.022	3.651
12	7.950	6.615	5.876	5.279	4.637	4.231
13	8.835	7.402	6.607	5.964	5.270	4.831
14	9.730	8.200	7.352	6.663	5.919	5.446
15	10.633	9.010	8.108	7.376	6.582	6.077
16	11.544	9.828	8.875	8.100	7.258	6.722
17	12.461	10.656	9.652	8.834	7.946	7.378
18	13.385	11.491	10.437	9.578	8.644	8.046
19	14.315	12.333	11.230	10.331	9.351	8.724
20	15.249	13.182	12.031	11.092	10.068	9.411
21	16.189	14.036	12.838	11.860	10.793	10.108
22	17.132	14.896	13.651	12.635	11.525	10.812
23	18.080	15.761	14.470	13.416	12.265	11.524
24	19.031	16.631	15.295	14.204	13.011	12.243
25	19.985	17.505	16.125	14.997	13.763	12.969
26	20.943	18.383	16.959	15.795	14.522	13.701
27	21.904	19.265	17.797	16.598	15.285	14.439
28	22.867	20.150	18.640	17.406	16.054	15.182
29	23.833	21.039	19.487	18.218	16.828	15.930
30	24.802	21.932	20.337	19.034	17.606	16.684
31	25.773	22.827	21.191	19.854	18.389	17.442
32	26.746	23.725	22.048	20.678	19.176	18.205
33	27.721	24.626	22.909	21.505	19.966	18.972
34	28.698	25.529	23.772	22.336	20.761	19.743
35	29.677	26.435	24.638	23.169	21.559	20.517
36	30.657	27.343	25.507	24.006	22.361	21.296
37	31.640	28.254	26.378	24.846	23.166	22.078
38	32.624	29.166	27.252	25.689	23.974	22.864
39	33.609	30.081	28.129	26.534	24.785	23.652
40	34.596	30.997	29.007	27.382	25.599	24.444
41	35.584	31.916	29.888	28.232	26.416	25.239
42	36.574	32.836	30.771	29.085	27.235	26.037
43	37.565	33.758	31.656	29.940	28.057	26.837
44	38.557	34.682	32.543	30.797	28.882	27.641
45	39.550	35.607	33.432	31.656	29.708	28.447
46	40.545	36.534	34.322	32.517	30.538	29.255
47	41.540	37.462	35.215	33.381	31.369	30.066
48	42.537	38.392	36.109	34.246	32.203	30.879
49	43.534	39.323	37.004	35.113	33.039	31.694
50	44.533	40.255	37.901	35.982	33.876	32.512
51	45.533	41.189	38.800	36.852	34.716	33.332
52	46.533	42.124	39.700	37.725	35.558	34.153
53	47.534	43.060	40.602	38.598	36.401	34.977
54	48.536	43.997	41.505	39.474	37.247	35.803
55	49.539	44.936	42.409	40.351	38.094	36.630
56	50.543	45.875	43.315	41.229	38.942	37.460
57	51.548	46.816	44.222	42.109	39.793	38.291
58	52.553	47.758	45.130	42.990	40.645	39.124
59	53.559	48.700	46.039	43.873	41.498	39.959
60	54.566	49.644	46.950	44.757	42.353	40.795
61	55.573	50.589	47.861	45.642	43.210	41.633
62	56.581	51.534	48.774	46.528	44.068	42.472
63	57.590	52.481	49.688	47.416	44.927	43.313
64	58.599	53.428	50.603	48.305	45.788	44.156
65	59.609	54.376	51.518	49.195	46.650	45.000
66	60.619	55.325	52.435	50.086	47.513	45.845
67	61.630	56.275	53.353	50.978	48.378	46.692
68	62.642	57.226	54.272	51.872	49.243	47.540
69	63.654	58.177	55.191	52.766	50.110	48.389
70	64.667	59.129	56.112	53.661	50.979	49.239
71	65.680	60.082	57.034	54.558	51.848	50.091
72	66.694	61.036	57.956	55.455	52.718	50.944
73	67.708	61.990	58.879	56.354	53.590	51.799
74	68.723	62.945	59.803	57.253	54.463	52.654
75	69.738	63.900	60.728	58.153	55.337	53.511

Trunks	0.05	0.02	0.01	0.005	0.002	0.001
	E	E	E	E	E	E
76	70.753	64.857	61.653	59.054	56.211	54.369
77	71.769	65.814	62.579	59.956	57.087	55.227
78	72.786	66.771	63.506	60.859	57.964	56.087
79	73.803	67.729	64.434	61.763	58.842	56.948
80	74.820	68.688	65.363	62.668	59.720	57.810
81	75.838	69.647	66.292	63.573	60.600	58.673
82	76.856	70.607	67.222	64.479	61.480	59.537
83	77.874	71.568	68.152	65.386	62.363	60.402
84	78.893	72.529	69.084	66.294	63.244	61.268
85	79.912	73.490	70.016	67.202	64.127	62.135
86	80.932	74.453	70.948	68.111	65.011	63.003
87	81.952	75.415	71.881	69.021	65.896	63.872
88	82.972	76.378	72.815	69.932	66.782	64.742
89	83.993	77.342	73.749	70.843	67.669	65.612
90	85.014	78.306	74.684	71.755	68.556	66.484
91	86.035	79.271	75.620	72.668	69.444	67.356
92	87.057	80.236	76.556	73.581	70.333	68.229
93	88.079	81.201	77.493	74.495	71.222	69.103
94	89.101	82.167	78.430	75.410	72.113	69.978
95	90.123	83.133	79.368	76.325	73.004	70.853
96	91.146	84.100	80.306	77.241	73.895	71.729
97	92.169	85.068	81.245	78.157	74.788	72.606
98	93.193	86.035	82.184	79.074	75.681	73.484
99	94.216	87.003	83.124	79.992	76.575	74.363
100	95.240	87.972	84.064	80.910	77.469	75.242
101	96.265	88.941	85.005	81.829	78.364	76.123
102	97.289	89.910	85.946	82.748	79.260	77.003
103	98.314	90.880	86.888	83.668	80.157	77.884
104	99.339	91.850	87.830	84.588	81.054	78.766
105	100.364	92.821	88.773	85.509	81.951	79.649
106	101.390	93.791	89.716	86.431	82.850	80.532
107	102.416	94.762	90.660	87.353	83.748	81.416
108	103.441	95.734	91.604	88.275	84.648	82.301
109	104.468	96.706	92.548	89.198	85.546	83.186
110	105.494	97.678	93.493	90.121	86.448	84.072
111	106.521	98.651	94.438	91.045	87.350	84.959
112	107.548	99.624	95.384	91.970	88.251	85.846
113	108.575	100.597	96.330	92.895	89.154	86.734
114	109.602	101.571	97.277	93.820	90.057	87.622
115	110.630	102.545	98.224	94.746	90.960	88.511
116	111.658	103.519	99.171	95.672	91.864	89.401
117	112.686	104.493	100.118	96.599	92.768	90.291
118	113.714	105.468	101.067	97.526	93.673	91.182
119	114.742	106.443	102.015	98.454	94.578	92.073
120	115.771	107.419	102.964	99.382	95.484	92.964
121	116.799	108.395	103.913	100.310	96.391	93.857
122	117.828	109.371	104.862	101.239	97.298	94.750
123	118.857	110.347	105.812	102.168	98.205	95.643
124	119.887	111.324	106.762	103.098	99.113	96.537
125	120.916	112.300	107.713	104.028	100.021	97.431
126	121.946	113.278	108.664	104.958	100.930	98.326
127	122.976	114.255	109.615	105.889	101.839	99.222
128	124.006	115.233	110.567	106.820	102.749	100.117
129	125.036	116.211	111.518	107.752	103.659	101.014
130	126.066	117.189	112.470	108.684	104.569	101.911
131	127.097	118.167	113.423	109.616	105.480	102.808
132	128.128	119.146	114.376	110.549	106.392	103.706
133	129.158	120.125	115.329	111.482	107.303	104.604
134	130.190	121.104	116.282	112.415	108.215	105.503
135	131.221	122.084	117.236	113.349	109.128	106.402
136	132.252	123.063	118.190	114.283	110.041	107.301
137	133.284	124.043	119.144	115.218	110.955	108.202
138	134.315	125.023	120.099	116.153	111.868	109.102
139	135.347	126.004	121.054	117.088	112.783	110.003
140	136.379	126.985	122.009	118.023	113.698	110.904
141	137.411	127.965	122.964	118.959	114.612	111.806
142	138.443	128.946	123.920	119.895	115.528	112.708
143	139.476	129.928	124.876	120.832	116.444	113.611
144	140.508	130.909	125.832	121.768	117.360	114.514
145	141.541	131.891	126.789	122.706	118.276	115.417
146	142.574	132.873	127.746	123.643	119.193	116.321
147	143.606	133.855	128.703	124.581	120.110	117.225
148	144.640	134.837	129.660	125.519	121.028	118.130
149	145.673	135.820	130.618	126.457	121.946	119.035
150	146.706	136.803	131.576	127.395	122.864	119.941

Trunks	0.05	0.02	0.01	0.005	0.002	0.001	Trunks	0.05	0.02	0.01	0.005	0.002	0.001
	E	E	E	E	E	E		E	E	E	E	E	E
151	147.739	137.786	132.534	128.334	123.783	120.846	226	225.525	211.955	204.948	199.412	193.459	189.637
152	148.773	138.769	133.492	129.274	124.702	121.752	227	226.565	212.948	205.920	200.366	194.396	190.563
153	149.807	139.752	134.451	130.213	125.621	122.659	228	227.605	213.942	206.892	201.321	195.333	191.490
154	150.840	140.738	135.409	131.153	126.541	123.566	229	228.645	214.936	207.864	202.276	196.271	192.416
155	151.874	141.720	136.368	132.093	127.461	124.473	230	229.685	215.930	208.835	203.232	197.209	193.343
156	152.908	142.704	137.328	133.033	128.381	125.384	231	230.726	216.923	209.807	204.187	198.147	194.270
157	153.943	143.688	138.287	133.974	129.302	126.288	232	231.766	217.918	210.780	205.142	199.085	195.198
158	154.977	144.672	139.247	134.915	130.222	127.197	233	232.806	218.912	211.751	206.098	200.023	196.126
159	156.011	145.657	140.207	135.856	131.144	128.105	234	233.846	219.907	212.723	207.053	200.962	197.053
160	157.046	146.641	141.167	136.797	132.065	129.014	235	234.887	220.901	213.696	208.009	201.901	197.981
161	158.080	147.626	142.128	137.739	132.987	129.924	236	235.928	221.895	214.669	208.965	202.840	198.909
162	159.115	148.611	143.088	138.681	133.910	130.834	237	236.968	222.890	215.641	209.921	203.779	199.838
163	160.150	149.596	144.049	139.623	134.832	131.743	238	238.009	223.884	216.614	210.878	204.718	200.767
164	161.185	150.582	145.010	140.565	135.755	132.654	239	239.049	224.879	217.587	211.834	205.657	201.695
165	162.220	151.567	145.971	141.508	136.678	133.564	240	240.089	225.874	218.560	212.791	206.597	202.624
166	163.255	152.553	146.933	142.451	137.601	134.476	241	241.130	226.868	219.533	213.747	207.536	203.553
167	164.290	153.539	147.895	143.394	138.525	135.387	242	242.171	227.864	220.507	214.705	208.477	204.482
168	165.326	154.525	148.857	144.338	139.449	136.299	243	243.212	228.859	221.480	215.661	209.417	205.412
169	166.361	155.511	149.819	145.281	140.373	137.210	244	244.254	229.854	222.454	216.619	210.357	206.341
170	167.397	156.498	150.781	146.225	141.298	138.123	245	245.294	230.850	223.427	217.576	211.297	207.271
171	168.433	157.484	151.744	147.170	142.223	139.035	246	246.335	231.844	224.401	218.533	212.238	208.201
172	169.468	158.471	152.706	148.114	143.148	139.948	247	247.376	232.840	225.374	219.491	213.178	209.131
173	170.504	159.458	153.669	149.058	144.073	140.861	248	248.417	233.835	226.348	220.449	214.120	210.061
174	171.540	160.445	154.633	150.003	144.999	141.775	249	249.458	234.831	227.323	221.406	215.060	210.992
175	172.577	161.432	155.596	150.949	145.925	142.689	250	250.500	235.827	228.297	222.364	216.001	211.922
176	173.613	162.419	156.559	151.894	146.851	143.603	251	251.541	236.823	229.270	223.322	216.943	212.853
177	174.649	163.407	157.523	152.839	147.777	144.517	252	252.582	237.818	230.245	224.280	217.884	213.784
178	175.685	164.394	158.487	153.785	148.704	145.432	253	253.624	238.814	231.220	225.239	218.826	214.715
179	176.722	165.382	159.451	154.731	149.631	146.347	254	254.665	239.810	232.194	226.197	219.767	215.646
180	177.758	166.370	160.416	155.677	150.558	147.262	255	255.707	240.806	233.169	227.156	220.709	216.578
181	178.795	167.358	161.380	156.624	151.486	148.178	256	256.748	241.802	234.143	228.115	221.652	217.509
182	179.832	168.347	162.345	157.570	152.414	149.094	257	257.790	242.799	235.118	229.073	222.593	218.441
183	180.869	169.335	163.310	158.517	153.341	150.010	258	258.831	243.796	236.093	230.032	223.536	219.373
184	181.905	170.324	164.275	159.464	154.270	150.926	259	259.872	244.792	237.069	230.991	224.479	220.305
185	182.942	171.312	165.240	160.412	155.198	151.843	260	260.915	245.789	238.044	231.951	225.421	221.237
186	183.980	172.301	166.205	161.359	156.127	152.760	261	261.957	246.785	239.019	232.910	226.364	222.170
187	185.017	173.290	167.171	162.307	157.056	153.677	262	262.998	247.781	239.995	233.869	227.307	223.103
188	186.054	174.279	168.137	163.255	157.985	154.594	263	264.040	248.778	240.970	234.829	228.249	224.036
189	187.091	175.268	169.102	164.203	158.915	155.512	264	265.082	249.774	241.945	235.788	229.193	224.968
190	188.129	176.257	170.068	165.151	159.845	156.430	265	266.124	250.772	242.921	236.748	230.137	225.901
191	189.166	177.247	171.035	166.100	160.775	157.348	266	267.166	251.769	243.896	237.707	231.079	226.835
192	190.204	178.237	172.001	167.048	161.705	158.267	267	268.208	252.766	244.872	238.668	232.023	227.768
193	191.241	179.226	172.968	167.997	162.635	159.186	268	269.250	253.762	245.848	239.628	232.967	228.702
194	192.279	180.216	173.934	168.946	163.566	160.104	269	270.292	254.760	246.824	240.588	233.911	229.635
195	193.317	181.206	174.901	169.896	164.497	161.024	270	271.334	255.757	247.801	241.549	234.855	230.569
196	194.355	182.197	175.868	170.845	165.428	161.943	271	272.376	256.755	248.776	242.508	235.799	231.503
197	195.393	183.186	176.835	171.795	166.359	162.863	272	273.418	257.752	249.753	243.470	236.743	232.437
198	196.431	184.177	177.803	172.745	167.291	163.783	273	274.460	258.750	250.730	244.430	237.688	233.372
199	197.469	185.168	178.770	173.695	168.223	164.703	274	275.502	259.747	251.706	245.391	238.632	234.306
200	198.507	186.158	179.738	174.645	169.155	165.624	275	276.545	260.744	252.682	246.352	239.578	235.240
201	199.546	187.149	180.706	175.595	170.087	166.545	276	277.588	261.743	253.659	247.312	240.522	236.175
202	200.584	188.140	181.674	176.546	171.019	167.466	277	278.630	262.740	254.636	248.274	241.467	237.110
203	201.623	189.131	182.642	177.497	171.952	168.387	278	279.673	263.738	255.613	249.235	242.412	238.045
204	202.661	190.122	183.610	178.448	172.885	169.309	279	280.715	264.736	256.590	250.196	243.357	238.980
205	203.699	191.113	184.579	179.399	173.818	170.230	280	281.757	265.734	257.567	251.158	244.302	239.915
206	204.738	192.105	185.548	180.350	174.751	171.152	281	282.800	266.732	258.544	252.120	245.247	240.850
207	205.776	193.096	186.516	181.302	175.685	172.074	282	283.842	267.730	259.521	253.081	246.193	241.786
208	206.816	194.088	187.485	182.253	176.619	172.996	283	284.886	268.728	260.498	254.042	247.140	242.722
209	207.855	195.079	188.454	183.205	177.552	173.919	284	285.928	269.726	261.476	255.004	248.085	243.658
210	208.893	196.071	189.423	184.157	178.486	174.842	285	286.971	270.725	262.453	255.966	249.031	244.594
211	209.932	197.063	190.393	185.109	179.421	175.763	286	288.014	271.723	263.431	256.929	249.977	245.530
212	210.972	198.055	191.362	186.062	180.355	176.688	287	289.057	272.721	264.409	257.890	250.923	246.466
213	212.011	199.047	192.331	187.014	181.290	177.613	288	290.099	273.719	265.386	258.853	251.870	247.403
214	213.049	200.039	193.301	187.967	182.225	178.536	289	291.143	274.718	266.364	259.815	252.816	248.339
215	214.089	201.031	194.271	188.920	183.160	179.459	290	292.185	275.716	267.342	260.778	253.763	249.276
216	215.129	202.024	195.241	189.873	184.095	180.383	291	293.228	276.715	268.321	261.740	254.709	250.212
217	216.168	203.017	196.211	190.826	185.031	181.308	292	294.271	277.714	269.298	262.703	255.657	251.150
218	217.207	204.010	197.182	191.779	185.966	182.233	293	295.314	278.713	270.276	263.665	256.604	252.086
219	218.247	205.002	198.152	192.733	186.902	183.157	294	296.357	279.712	271.255	264.629	257.550	253.024
220	219.286	205.995	199.123	193.686	187.838	184.082	295	297.400	280.711	272.233	265.591	258.497	253.961
221	220.326	206.988	200.094	194.640	188.775	185.007	296	298.443	281.710	273.211	266.555	259.444	254.898
222	221.365	207.981	201.064	195.594	189.711	185.933	297	299.486	282.709	274.189	267.517	260.392	255.835
223	222.405	208.974	202.035	196.549	190.647	186.859	298	300.529	283.708	275.168	268.481	261.339	256.774
224	223.445	209.968	203.006	197.503	191.584	187.784	299	301.573	284.707	276.146	269.444	262.287	257.711
225	224.485	210.961	203.977	198.457	192.521	188.710	300	302.616	285.706	277.125	270.407	263.235	258.650