

Table 1: Evaluation Results of Neighbourhood-based QoS Prediction Approaches

MAE												
Approach	Response Time						Throughput					
	5%	10%	15%	20%	25%	30%	5%	10%	15%	20%	25%	30%
UMEAN [15]	0.8763	0.8750	0.8751	0.8747	0.8747	0.8745	53.8757	53.8347	53.8155	53.8008	53.8037	53.7990
IMEAN [15]	0.7017	0.6879	0.6833	0.6809	0.6795	0.6785	27.2885	26.8596	26.7156	26.6410	26.5933	26.5713
UPCC [15]	0.6359	0.5547	0.5148	0.4863	0.4670	0.4539	27.2180	22.6122	20.4715	19.2612	18.2583	17.4624
IPCC [15]	0.6344	0.5940	0.5099	0.4560	0.4328	0.4156	27.0185	26.1948	25.5579	23.9729	22.5754	21.5654
UIPCC [15]	0.6253	0.5815	0.5012	0.4498	0.4274	0.4110	26.7568	22.3700	20.2190	18.9276	17.8910	17.0797
ADF [12]	0.6094	0.5443	0.4974	0.4636	0.4429	0.4276	24.9961	21.5013	18.5685	16.6536	15.5644	14.8244
NRCF [10]	0.5532	0.4905	0.4511	0.4261	0.4151	0.4059	23.3275	18.8571	16.0284	14.3444	13.4289	12.8267
RMSE												
Approach	Response Time						Throughput					
	5%	10%	15%	20%	25%	30%	5%	10%	15%	20%	25%	30%
UMEAN [15]	1.8529	1.8555	1.8552	1.8554	1.8551	1.8553	110.3693	110.3802	110.3817	110.3822	110.3741	110.3927
IMEAN [15]	1.5673	1.5425	1.5327	1.5280	1.5251	1.5238	66.1012	64.8083	64.3864	64.1772	64.0426	63.9630
UPCC [15]	1.3797	1.3110	1.2597	1.2198	1.1909	1.1712	61.0180	54.5530	51.0145	48.8585	47.1670	45.8735
IPCC [15]	1.3987	1.3435	1.2611	1.2071	1.1757	1.1519	63.0017	60.3981	57.7614	54.8811	52.6665	51.0218
UIPCC [15]	1.3879	1.3302	1.2498	1.1968	1.1657	1.1422	60.7985	54.4563	50.7043	48.2950	46.4539	45.0599
ADF [12]	1.3613	1.2924	1.2325	1.1898	1.1617	1.1398	60.7939	54.2893	48.8074	45.2008	43.1359	41.7186
NRCF [10]	1.4547	1.3678	1.3050	1.2581	1.2250	1.1975	59.9498	52.9977	48.1072	44.5142	42.2524	40.7493
NMAE												
Approach	Response Time						Throughput					
	5%	10%	15%	20%	25%	30%	5%	10%	15%	20%	25%	30%
UMEAN [15]	0.9664	0.9635	0.9635	0.9629	0.9630	0.9628	1.1338	1.1321	1.1314	1.1310	1.1311	1.1308
IMEAN [15]	0.7738	0.7575	0.7524	0.7496	0.7481	0.7470	0.5743	0.5648	0.5617	0.5601	0.5591	0.5585
UPCC [15]	0.7013	0.6108	0.5668	0.5353	0.5141	0.4997	0.5728	0.4755	0.4304	0.4049	0.3838	0.3670
IPCC [15]	0.6996	0.6540	0.5614	0.5019	0.4764	0.4576	0.5686	0.5509	0.5373	0.5040	0.4746	0.4533
UIPCC [15]	0.6896	0.6404	0.5519	0.4952	0.4705	0.4525	0.5631	0.4704	0.4251	0.3979	0.3761	0.3590
ADF [12]	0.6720	0.5993	0.5477	0.5103	0.4876	0.4707	0.5260	0.4522	0.3904	0.3501	0.3272	0.3116
NRCF [10]	0.6101	0.5401	0.4967	0.4691	0.4570	0.4468	0.4909	0.3966	0.3370	0.3016	0.2823	0.2696
MRE												
Approach	Response Time						Throughput					
	5%	10%	15%	20%	25%	30%	5%	10%	15%	20%	25%	30%
UMEAN [15]	1.3058	1.3091	1.3151	1.3145	1.3172	1.3174	2.2995	2.3121	2.3148	2.3152	2.3175	2.3163
IMEAN [15]	0.6677	0.6970	0.7086	0.7145	0.7185	0.7210	0.5297	0.5333	0.5349	0.5356	0.5360	0.5365
UPCC [15]	0.6594	0.5216	0.4830	0.4569	0.4394	0.4235	0.6668	0.5099	0.4306	0.3891	0.3576	0.3347
IPCC [15]	0.6160	0.5890	0.4616	0.3537	0.3163	0.2935	0.5945	0.5921	0.5860	0.5372	0.4935	0.4642
UIPCC [15]	0.5967	0.5618	0.4460	0.3539	0.3205	0.3002	0.6527	0.5074	0.4291	0.3828	0.3494	0.3259
ADF [12]	0.6146	0.5136	0.4529	0.4143	0.3940	0.3774	0.5797	0.4883	0.3913	0.3248	0.2896	0.2675
NRCF [10]	0.4033	0.3382	0.2789	0.2530	0.2514	0.2517	0.4266	0.3274	0.2532	0.2141	0.1968	0.1856
NPRE												
Approach	Response Time						Throughput					
	5%	10%	15%	20%	25%	30%	5%	10%	15%	20%	25%	30%
UMEAN [15]	9.2343	9.2335	9.2480	9.2459	9.2566	9.2554	17.8638	17.8177	17.8127	17.7967	17.7929	17.7830
IMEAN [15]	4.3077	4.2745	4.2668	4.2625	4.2601	4.2576	3.1772	3.0898	3.0501	3.0272	3.0136	3.0050
UPCC [15]	5.5978	4.1200	3.6251	3.3176	3.1152	2.9503	8.3154	7.7074	7.4214	7.1987	6.7925	6.3599
IPCC [15]	4.4292	4.1514	3.2360	2.5782	2.3050	2.0965	4.7127	4.9762	5.5102	5.2150	4.7597	4.4117
UIPCC [15]	4.5003	4.1258	3.2564	2.6307	2.3674	2.1710	8.0135	7.5149	7.3230	7.1106	6.7261	6.3274
ADF [12]	4.7865	3.7758	3.2212	2.8909	2.7128	2.5864	4.6144	4.1495	3.8572	3.7294	3.5844	3.4497
NRCF [10]	2.5381	2.0027	1.7365	1.6232	1.6536	1.6769	2.6504	2.0731	1.7598	1.5716	1.4706	1.4015

Table 2: Evaluation Results of Model-based QoS Prediction Approaches

MAE												
Approach	Response Time						Throughput					
	5%	10%	15%	20%	25%	30%	5%	10%	15%	20%	25%	30%
PMF [8, 16]	0.5690	0.4867	0.4522	0.4311	0.4177	0.4086	19.0823	15.9936	14.6698	13.9236	13.4048	13.1173
NMF [4, 14]	0.5456	0.4783	0.4466	0.4272	0.4144	0.4055	18.8833	15.5489	14.2457	13.5776	13.1026	12.7937
Biased-MF [3, 10]	0.5958	0.5130	0.4783	0.4574	0.4399	0.4288	21.8355	17.8525	15.9327	14.9078	14.1317	13.7331
CloudPred [14]	0.5435	0.4777	0.4401	0.4184	0.4038	0.3945	22.5235	19.9348	18.4965	17.5144	16.7963	16.2580
EMF [5]	0.5573	0.4836	0.4476	0.4274	0.4140	0.4039	20.1113	15.8019	14.3130	13.5178	13.0998	12.8558
NIMF [16]	0.5542	0.4800	0.4428	0.4202	0.4074	0.3991	18.8722	15.1540	13.8093	13.2026	12.8584	12.6341
LN-LFM [10]	0.5598	0.5001	0.4712	0.4529	0.4419	0.4356	20.4282	17.7124	16.7972	16.3722	16.1699	15.9871

RMSE												
Approach	Response Time						Throughput					
	5%	10%	15%	20%	25%	30%	5%	10%	15%	20%	25%	30%
PMF [8, 16]	1.5371	1.3164	1.2206	1.1690	1.1392	1.1205	57.8830	48.0713	44.0125	41.7137	40.3004	39.4392
NMF [4, 14]	1.4726	1.2833	1.2018	1.1604	1.1353	1.1193	57.5021	47.7830	43.8441	41.7270	40.3765	39.4957
Biased-MF [3, 10]	1.3833	1.2622	1.2096	1.1786	1.1568	1.1425	56.8648	48.2394	44.3041	42.1485	40.6480	39.7155
CloudPred [14]	1.3281	1.2238	1.1689	1.1365	1.1140	1.0986	55.3939	50.3517	47.6415	45.6791	44.1835	43.0918
EMF [5]	1.4857	1.2893	1.2033	1.1582	1.1305	1.1116	58.8343	48.3694	44.0889	41.6515	40.2107	39.2927
NIMF [16]	1.4791	1.2950	1.2082	1.1592	1.1295	1.1097	56.1480	46.9792	43.2501	41.2408	39.9317	39.0943
LN-LFM [10]	1.3055	1.2278	1.1815	1.1549	1.1385	1.1273	52.4372	46.9689	44.9432	44.1694	43.6825	43.4871

MAE												
Approach	Response Time						Throughput					
	5%	10%	15%	20%	25%	30%	5%	10%	15%	20%	25%	30%
PMF [8, 16]	0.6275	0.5359	0.4979	0.4745	0.4599	0.4498	0.4016	0.3363	0.3084	0.2927	0.2818	0.2757
NMF [4, 14]	0.6017	0.5266	0.4918	0.4702	0.4562	0.4465	0.3974	0.3270	0.2995	0.2854	0.2754	0.2689
Biased-MF [3, 10]	0.6571	0.5649	0.5266	0.5035	0.4843	0.4721	0.4595	0.3754	0.3350	0.3134	0.2971	0.2886
CloudPred [14]	0.5993	0.5260	0.4846	0.4606	0.4446	0.4343	0.4740	0.4192	0.3889	0.3682	0.3531	0.3417
EMF [5]	0.6146	0.5325	0.4928	0.4705	0.4558	0.4446	0.4232	0.3323	0.3009	0.2842	0.2754	0.2702
NIMF [16]	0.6112	0.5285	0.4875	0.4625	0.4486	0.4393	0.3971	0.3187	0.2903	0.2776	0.2703	0.2655
LN-LFM [10]	0.6174	0.5507	0.5188	0.4986	0.4865	0.4796	0.4299	0.3725	0.3532	0.3442	0.3399	0.3360

MRE												
Approach	Response Time						Throughput					
	5%	10%	15%	20%	25%	30%	5%	10%	15%	20%	25%	30%
PMF [8, 16]	0.5144	0.4286	0.4025	0.3851	0.3725	0.3645	0.3112	0.2708	0.2525	0.2423	0.2335	0.2294
NMF [4, 14]	0.4818	0.4219	0.4001	0.3830	0.3707	0.3620	0.3063	0.2570	0.2390	0.2301	0.2234	0.2187
Biased-MF [3, 10]	0.6860	0.5178	0.4734	0.4526	0.4273	0.4130	0.5156	0.3873	0.3353	0.3095	0.2886	0.2786
CloudPred [14]	0.5469	0.4730	0.4140	0.3804	0.3591	0.3454	0.5176	0.4271	0.3826	0.3556	0.3367	0.3226
EMF [5]	0.4686	0.4164	0.3930	0.3784	0.3664	0.3576	0.3896	0.2786	0.2492	0.2352	0.2295	0.2264
NIMF [16]	0.4859	0.4293	0.3966	0.3720	0.3585	0.3495	0.3044	0.2425	0.2237	0.2172	0.2152	0.2132
LN-LFM [10]	0.5878	0.5037	0.4683	0.4428	0.4276	0.4229	0.4906	0.4148	0.3952	0.3803	0.3753	0.3647

NPRE												
Approach	Response Time						Throughput					
	5%	10%	15%	20%	25%	30%	5%	10%	15%	20%	25%	30%
PMF [8, 16]	1.8162	2.1960	2.1914	2.1316	2.0762	2.0337	1.4547	1.4247	1.3833	1.3585	1.3244	1.3147
NMF [4, 14]	2.0066	2.3021	2.2963	2.2404	2.1865	2.1315	1.4693	1.3342	1.2627	1.2303	1.1843	1.1573
Biased-MF [3, 10]	4.8683	3.5361	3.0439	2.7945	2.5626	2.4306	4.6908	3.2163	2.6142	2.3355	2.1041	2.0033
CloudPred [14]	3.8729	3.2464	2.8188	2.5919	2.4458	2.3514	6.5436	5.8759	5.3486	4.9433	4.6368	4.4104
EMF [5]	2.6127	2.5441	2.3474	2.2196	2.1266	2.0444	2.4646	1.7207	1.5575	1.4695	1.4209	1.3960
NIMF [16]	2.2789	2.4370	2.3098	2.1698	2.0800	2.0205	1.6421	1.3019	1.2019	1.1757	1.1818	1.1832
LN-LFM [10]	3.7801	3.1867	2.9785	2.7995	2.6957	2.6775	4.6086	4.0354	3.8556	3.7543	3.7375	3.6324

Table 3: Evaluation Results of Location-aware QoS Prediction Approaches

MAE												
Approach	Response Time						Throughput					
	5%	10%	15%	20%	25%	30%	5%	10%	15%	20%	25%	30%
RegionKNN [1]	0.5883	0.5477	0.5258	0.5158	0.5148	0.5091	25.6324	24.8380	24.5841	24.0361	23.6822	23.7984
LACF [11]	0.6374	0.5659	0.5159	0.4827	0.4614	0.4453	23.1685	19.6257	17.7949	16.6669	15.8503	15.2358
LBR [5]	0.5499	0.4802	0.4491	0.4300	0.4186	0.4103	18.3187	15.4272	14.2711	13.6512	13.2115	12.9824
HMF [6]	0.5595	0.4815	0.4490	0.4296	0.4165	0.4072	19.1320	15.7187	14.3719	13.6319	13.1127	12.7767
LoRec [2]	0.6479	0.5557	0.5018	0.4659	0.4415	0.4437	27.7773	24.7118	23.1466	21.7440	20.7727	20.5338

RMSE												
Approach	Response Time						Throughput					
	5%	10%	15%	20%	25%	30%	5%	10%	15%	20%	25%	30%
RegionKNN [1]	1.5426	1.5129	1.5129	1.5214	1.5202	1.5193	67.8678	67.5510	67.3137	66.1760	65.4074	65.5971
LACF [11]	1.4436	1.3420	1.2759	1.2298	1.1964	1.1720	58.9666	53.1050	49.7659	47.6247	46.0144	44.7729
LBR [5]	1.4741	1.2858	1.2036	1.1610	1.1371	1.1214	56.0215	47.0197	43.3639	41.3552	40.0663	39.2269
HMF [6]	1.5248	1.3105	1.2162	1.1661	1.1365	1.1178	58.7088	48.3461	44.0537	41.6678	40.1066	39.0613
LoRec [2]	1.3957	1.3087	1.2467	1.2040	1.1668	1.1504	62.5533	58.4275	56.1037	54.0139	52.2326	52.0747

NMAE												
Approach	Response Time						Throughput					
	5%	10%	15%	20%	25%	30%	5%	10%	15%	20%	25%	30%
RegionKNN [1]	0.6488	0.6031	0.5790	0.5678	0.5668	0.5605	0.5394	0.5223	0.5169	0.5053	0.4979	0.5002
LACF [11]	0.7029	0.6232	0.5680	0.5313	0.5080	0.4903	0.4876	0.4127	0.3741	0.3504	0.3332	0.3202
LBR [5]	0.6064	0.5287	0.4945	0.4733	0.4609	0.4517	0.3855	0.3244	0.3000	0.2870	0.2777	0.2729
HMF [6]	0.6170	0.5302	0.4944	0.4729	0.4586	0.4483	0.4026	0.3306	0.3022	0.2866	0.2757	0.2685
LoRec [2]	0.7145	0.6119	0.5525	0.5129	0.4861	0.4885	0.5845	0.5197	0.4866	0.4571	0.4367	0.4316

MRE												
Approach	Response Time						Throughput					
	5%	10%	15%	20%	25%	30%	5%	10%	15%	20%	25%	30%
RegionKNN [1]	0.4889	0.3956	0.3385	0.3176	0.3092	0.3019	0.4929	0.4497	0.4413	0.4194	0.4049	0.4123
LACF [11]	0.5529	0.4849	0.4265	0.3879	0.3669	0.3520	0.5134	0.4193	0.3681	0.3357	0.3134	0.2972
LBR [5]	0.4821	0.4191	0.3943	0.3776	0.3695	0.3640	0.2965	0.2582	0.2428	0.2350	0.2278	0.2259
HMF [6]	0.4922	0.4116	0.3907	0.3782	0.3686	0.3614	0.3075	0.2592	0.2416	0.2323	0.2248	0.2202
LoRec [2]	0.6702	0.5273	0.4521	0.3998	0.3615	0.3717	0.6633	0.5445	0.4804	0.4238	0.4004	0.4008

NPRE												
Approach	Response Time						Throughput					
	5%	10%	15%	20%	25%	30%	5%	10%	15%	20%	25%	30%
RegionKNN [1]	2.9639	2.0452	1.5207	1.3125	1.2801	1.2033	3.4269	2.2582	2.1699	2.1450	2.1515	2.0403
LACF [11]	4.0485	3.3672	2.9025	2.6044	2.4324	2.2977	3.8434	3.2668	2.9680	2.7140	2.4993	2.3275
LBR [5]	2.0633	2.2241	2.1699	2.0943	2.0560	2.0225	1.3947	1.3562	1.3267	1.3162	1.2960	1.2945
HMF [6]	1.7817	2.1605	2.1796	2.1391	2.0871	2.0401	1.3952	1.3439	1.3108	1.2888	1.2617	1.2513
LoRec [2]	5.2303	3.8175	3.1082	2.6867	2.4068	2.4460	6.7456	5.4886	4.7837	4.0684	3.6106	3.2309

Table 4: Evaluation Results of Time-aware QoS Prediction Approaches

MAE												
Approach	Response Time						Throughput					
	5%	10%	15%	20%	25%	30%	5%	10%	15%	20%	25%	30%
UMEAN [15]	1.4201	1.4449	1.4529	1.4555	1.4565	1.4569	15.2671	15.2288	15.2199	15.2132	15.2100	15.2075
IMEAN [15]	1.2389	1.2024	1.1883	1.1809	1.1764	1.1734	8.3861	8.0263	7.8969	7.8286	7.7875	7.7578
UPCC [15]	1.0636	0.9783	0.9218	0.8811	0.8504	0.8268	10.3878	9.4950	8.9188	8.4699	8.1349	7.8855
IPCC [15]	1.0896	1.0100	1.0021	1.0033	0.9907	0.9606	10.0606	9.6574	9.4841	8.9271	8.3542	7.9722
UIPCC [15]	1.0434	0.9612	0.9122	0.8790	0.8514	0.8266	9.9087	9.3048	8.9362	8.3875	7.8750	7.5165
PMF [8, 16]	1.0148	0.9336	0.8951	0.8667	0.8448	0.8271	6.5710	5.9808	5.8312	5.6997	5.5512	5.3862
TF [7, 14]	0.8263	0.7759	0.7458	0.7430	0.7341	0.7338	4.2696	4.1635	4.1781	4.1086	4.1989	4.1090
WSPred [14]	0.7925	0.7684	0.7563	0.7653	0.7512	0.7638	4.1786	4.0656	4.0481	4.0869	4.0570	4.0550
CLUS [9]	0.9194	0.8858	0.8557	0.8296	0.8082	0.7926	5.6281	4.7686	4.1980	3.8712	3.6444	3.4931
NTF [13]	0.7509	0.7405	0.7376	0.7356	0.7346	0.7328	4.2134	4.0925	4.0513	4.0270	4.0072	3.9990
AMF [19]	0.7604	0.7288	0.7125	0.7034	0.6979	0.6936	5.8095	5.5427	5.4985	5.4356	5.3587	5.2974

RMSE												
Approach	Response Time						Throughput					
	5%	10%	15%	20%	25%	30%	5%	10%	15%	20%	25%	30%
UMEAN [15]	2.7445	2.8293	2.8559	2.8658	2.8694	2.8709	54.0243	53.9425	53.9018	53.9128	53.8885	53.8843
IMEAN [15]	2.4799	2.3860	2.3522	2.3350	2.3244	2.3170	43.9928	42.4968	42.0004	41.7880	41.6370	41.5441
UPCC [15]	2.1126	1.9830	1.9240	1.8817	1.8474	1.8189	43.2208	40.6727	38.8015	37.2579	35.9572	34.9025
IPCC [15]	2.2091	2.0629	2.0341	2.0268	2.0111	1.9718	45.2908	43.0893	42.4437	41.1497	39.5365	38.0906
UIPCC [15]	2.0943	1.9750	1.9204	1.8801	1.8443	1.8118	43.8901	41.5245	40.1929	38.6693	37.0395	35.5733
PMF [8, 16]	2.4969	2.2441	2.0951	1.9961	1.9271	1.8773	40.2913	36.0049	33.8467	32.4925	31.3060	30.3206
TF [7, 14]	1.8686	1.7826	1.7413	1.7323	1.7211	1.7204	23.9737	22.7832	22.1284	21.8622	21.9740	21.5785
WSPred [14]	1.8168	1.7878	1.7737	1.7864	1.7708	1.7921	23.6117	22.3649	22.0314	22.1614	21.9440	21.8858
CLUS [9]	2.2225	2.2625	2.2494	2.2168	2.1782	2.1434	34.5488	31.0865	28.2595	26.5021	25.2313	24.2964
NTF [13]	1.7423	1.7296	1.7259	1.7240	1.7223	1.7211	24.2157	23.0433	22.2431	21.9975	21.7521	21.6851
AMF [19]	2.0554	2.0026	1.9780	1.9687	1.9660	1.9630	42.0305	41.1129	43.2850	43.8825	43.8244	43.2458

NMAE												
Approach	Response Time						Throughput					
	5%	10%	15%	20%	25%	30%	5%	10%	15%	20%	25%	30%
UMEAN [15]	0.9956	0.9921	0.9912	0.9906	0.9903	0.9902	1.3431	1.3405	1.3400	1.3394	1.3392	1.3392
IMEAN [15]	0.8689	0.8260	0.8111	0.8041	0.8003	0.7980	0.7368	0.7056	0.6944	0.6884	0.6848	0.6823
UPCC [15]	0.7457	0.6718	0.6291	0.5998	0.5784	0.5622	0.9126	0.8350	0.7849	0.7457	0.7164	0.6947
IPCC [15]	0.7641	0.6939	0.6841	0.6831	0.6739	0.6532	0.8841	0.8489	0.8337	0.7851	0.7353	0.7022
UIPCC [15]	0.7315	0.6601	0.6225	0.5984	0.5791	0.5620	0.8706	0.8180	0.7858	0.7379	0.6933	0.6621
PMF [8, 16]	0.7117	0.6414	0.6110	0.5903	0.5748	0.5626	0.5783	0.5268	0.5139	0.5024	0.4894	0.4750
TF [7, 14]	0.5794	0.5330	0.5090	0.5059	0.4994	0.4990	0.3760	0.3670	0.3683	0.3623	0.3701	0.3624
WSPred [14]	0.5557	0.5280	0.5165	0.5215	0.5113	0.5198	0.3676	0.3580	0.3566	0.3600	0.3575	0.3574
CLUS [9]	0.6447	0.6088	0.5845	0.5653	0.5500	0.5392	0.4948	0.4194	0.3695	0.3408	0.3212	0.3080
NTF [13]	0.5264	0.5087	0.5035	0.5010	0.4998	0.4984	0.3712	0.3609	0.3574	0.3552	0.3535	0.3528
AMF [19]	0.5771	0.5512	0.5383	0.5313	0.5270	0.5237	0.5125	0.4885	0.4845	0.4789	0.4723	0.4668

MRE												
Approach	Response Time						Throughput					
	5%	10%	15%	20%	25%	30%	5%	10%	15%	20%	25%	30%
UMEAN [15]	1.8397	1.8505	1.8547	1.8559	1.8569	1.8580	3.9551	4.0523	4.0865	4.1033	4.1139	4.1212
IMEAN [15]	0.8826	1.0021	1.1090	1.1721	1.2123	1.2407	0.5662	0.5563	0.5549	0.5544	0.5543	0.5542
UPCC [15]	0.8920	0.7928	0.7084	0.6544	0.6182	0.5925	1.8669	1.6490	1.5204	1.4142	1.3296	1.2613
IPCC [15]	0.7695	0.7845	0.7954	0.7873	0.7651	0.7399	0.7761	0.7855	0.7704	0.7127	0.6583	0.6258
UIPCC [15]	0.8822	0.7742	0.6930	0.6459	0.6139	0.5883	1.4997	1.4344	1.3730	1.2621	1.1609	1.0970
PMF [8, 16]	0.5987	0.5586	0.5640	0.5661	0.5661	0.5646	0.5083	0.4617	0.4527	0.4420	0.4310	0.4194
TF [7, 14]	0.5561	0.5166	0.5011	0.5085	0.5031	0.5023	0.3396	0.3362	0.3411	0.3356	0.3509	0.3379
WSPred [14]	0.5224	0.5073	0.4929	0.5066	0.4864	0.5020	0.3188	0.3172	0.3177	0.3272	0.3210	0.3217
CLUS [9]	0.4391	0.3292	0.2752	0.2456	0.2301	0.2221	0.4015	0.2987	0.2409	0.2111	0.1948	0.1848
NTF [13]	0.4918	0.4785	0.4768	0.4744	0.4716	0.4681	0.3278	0.3203	0.3213	0.3185	0.3182	0.3180
AMF [19]	0.3429	0.3096	0.2923	0.2807	0.2726	0.2667	0.3914	0.3551	0.3326	0.3178	0.3079	0.3007

NPRE												
Approach	Response Time						Throughput					
	5%	10%	15%	20%	25%	30%	5%	10%	15%	20%	25%	30%
UMEAN [15]	11.4755	11.4484	11.4436	11.4362	11.4324	11.4327	27.9692	27.9576	27.9318	27.9059	27.8980	27.8968
IMEAN [15]	7.4207	7.4003	7.3733	7.3572	7.3466	7.3413	6.7739	6.8851	6.9254	6.9454	6.9585	6.9692
UPCC [15]	8.0327	7.2598	6.4785	5.8735	5.4423	5.1345	17.9732	17.3091	17.0590	16.8895	16.8247	16.8329
IPCC [15]	6.4997	6.0802	6.2072	6.4654	6.4501	6.1467	10.9426	11.4543	11.3848	10.4444	9.4234	8.8083
UIPCC [15]	7.6255	6.9048	6.3017	5.8920	5.5653	5.2678	15.0420	15.0629	14.9362	14.2859	13.6236	13.2575
PMF [8, 16]	2.4800	3.1464	3.4131	3.5144	3.5519	3.5530	1.6496	2.1302	2.3445	2.4244	2.4434	2.4354
TF [7, 14]	3.7143	3.3970	3.1640	3.1715	3.1027	3.0971	2.4907	2.5882	2.6310	2.6453	2.7091	2.6751
WSPred [14]	3.4195	3.1171	2.9515	3.0454	2.8489	2.9783	2.3020	2.4759	2.5290	2.5713	2.5890	2.6001
CLUS [9]	3.7684	2.9131	2.3956	2.0874	1.9023	1.7986	2.9901	2.3225	1.9294	1.6990	1.5685	1.4880
NTF [13]	3.3308	3.2532	3.2334	3.2033	3.2047	3.1773	2.3779	2.4355	2.4495	2.4454	2.4709	2.4982
AMF [19]	1.1030	0.9728	0.9272	0.8994	0.8799	0.8667	1.5757	1.3506	1.1833	1.0622	0.9934	0.9607

Table 5: Evaluation Results of Ranking-based QoS Prediction Approaches

NDCG@1												
Approach	Response Time						Throughput					
	5%	10%	15%	20%	25%	30%	5%	10%	15%	20%	25%	30%
UMEAN [15]	0.7635	0.8428	0.8861	0.9129	0.9310	0.9445	0.8681	0.9283	0.9517	0.9642	0.9725	0.9787
IMEAN [15]	0.7192	0.8196	0.8806	0.9097	0.9316	0.9450	0.8467	0.9100	0.9413	0.9570	0.9674	0.9747
UPCC [15]	0.7048	0.8123	0.8733	0.9053	0.9294	0.9434	0.8467	0.9120	0.9413	0.9571	0.9663	0.9739
IPCC [15]	0.7167	0.8181	0.8785	0.9076	0.9289	0.9437	0.8448	0.9115	0.9434	0.9589	0.9696	0.9768
UIPCC [15]	0.7184	0.8181	0.8786	0.9078	0.9290	0.9437	0.8475	0.9124	0.9434	0.9581	0.9682	0.9755
PMF [8, 16]	0.7640	0.8429	0.8842	0.9081	0.9240	0.9360	0.8758	0.9289	0.9468	0.9560	0.9618	0.9685
GreedyRank [18]	0.6078	0.6583	0.6973	0.7226	0.7537	0.7736	0.7779	0.8053	0.8288	0.8449	0.8636	0.8773
CloudRank [17]	0.6116	0.6702	0.7171	0.7540	0.7953	0.8210	0.7799	0.8138	0.8443	0.8677	0.8908	0.9066
NDCG@5												
Approach	Response Time						Throughput					
	5%	10%	15%	20%	25%	30%	5%	10%	15%	20%	25%	30%
UMEAN [15]	0.6279	0.7536	0.8100	0.8454	0.8718	0.8924	0.7329	0.8478	0.8955	0.9221	0.9396	0.9519
IMEAN [15]	0.6849	0.7604	0.8139	0.8486	0.8754	0.8951	0.8095	0.8582	0.8908	0.9141	0.9324	0.9456
UPCC [15]	0.6774	0.7549	0.8075	0.8423	0.8714	0.8911	0.8142	0.8643	0.8953	0.9166	0.9321	0.9441
IPCC [15]	0.6830	0.7613	0.8156	0.8484	0.8741	0.8938	0.8126	0.8628	0.8948	0.9185	0.9367	0.9495
UIPCC [15]	0.6836	0.7618	0.8160	0.8486	0.8745	0.8942	0.8144	0.8650	0.8971	0.9193	0.9352	0.9471
PMF [8, 16]	0.6679	0.7619	0.8111	0.8439	0.8688	0.8885	0.8129	0.8785	0.9079	0.9259	0.9390	0.9492
GreedyRank [18]	0.6182	0.6499	0.6777	0.7023	0.7270	0.7469	0.7934	0.8097	0.8241	0.8419	0.8584	0.8710
CloudRank [17]	0.6239	0.6657	0.7037	0.7407	0.7770	0.8056	0.7726	0.8041	0.8271	0.8482	0.8707	0.8869
NDCG@10												
Approach	Response Time						Throughput					
	5%	10%	15%	20%	25%	30%	5%	10%	15%	20%	25%	30%
UMEAN [15]	0.5385	0.6931	0.7741	0.8197	0.8496	0.8718	0.6349	0.7789	0.8453	0.8841	0.9098	0.9280
IMEAN [15]	0.6892	0.7504	0.7963	0.8287	0.8551	0.8754	0.7943	0.8347	0.8631	0.8854	0.9053	0.9220
UPCC [15]	0.6847	0.7507	0.7959	0.8277	0.8538	0.8732	0.8017	0.8452	0.8756	0.8978	0.9146	0.9277
IPCC [15]	0.6889	0.7549	0.8032	0.8337	0.8575	0.8763	0.7988	0.8411	0.8695	0.8939	0.9139	0.9296
UIPCC [15]	0.6896	0.7560	0.8039	0.8342	0.8578	0.8768	0.8018	0.8461	0.8770	0.9000	0.9177	0.9311
PMF [8, 16]	0.6705	0.7527	0.7960	0.8264	0.8506	0.8708	0.7976	0.8615	0.8916	0.9111	0.9261	0.9374
GreedyRank [18]	0.6361	0.6636	0.6867	0.7083	0.7281	0.7463	0.7629	0.7860	0.8034	0.8182	0.8346	0.8510
CloudRank [17]	0.6425	0.6800	0.7136	0.7461	0.7756	0.8016	0.7672	0.7976	0.8212	0.8415	0.8614	0.8780
NDCG@20												
Approach	Response Time						Throughput					
	5%	10%	15%	20%	25%	30%	5%	10%	15%	20%	25%	30%
UMEAN [15]	0.4446	0.5961	0.6944	0.7634	0.8133	0.8484	0.5136	0.6760	0.7636	0.8181	0.8561	0.8840
IMEAN [15]	0.7091	0.7577	0.7943	0.8220	0.8447	0.8640	0.7839	0.8172	0.8410	0.8602	0.8764	0.8911
UPCC [15]	0.7086	0.7633	0.8022	0.8306	0.8541	0.8719	0.7951	0.8342	0.8622	0.8837	0.9009	0.9146
IPCC [15]	0.7108	0.7673	0.8110	0.8387	0.8593	0.8761	0.7897	0.8243	0.8494	0.8725	0.8932	0.9100
UIPCC [15]	0.7118	0.7682	0.8118	0.8395	0.8601	0.8767	0.7950	0.8346	0.8632	0.8851	0.9028	0.9172
PMF [8, 16]	0.6931	0.7688	0.8080	0.8339	0.8544	0.8712	0.7908	0.8522	0.8815	0.9011	0.9156	0.9275
GreedyRank [18]	0.6701	0.6930	0.7121	0.7288	0.7461	0.7619	0.7619	0.7840	0.8009	0.8161	0.8315	0.8480
CloudRank [17]	0.6771	0.7092	0.7370	0.7623	0.7872	0.8093	0.7670	0.7966	0.8189	0.8381	0.8555	0.8717
NDCG@50												
Approach	Response Time						Throughput					
	5%	10%	15%	20%	25%	30%	5%	10%	15%	20%	25%	30%
UMEAN [15]	0.3294	0.4573	0.5481	0.6176	0.6750	0.7233	0.3653	0.5115	0.6107	0.6837	0.7401	0.7844
IMEAN [15]	0.7489	0.7853	0.8125	0.8329	0.8505	0.8656	0.7877	0.8158	0.8341	0.8492	0.8627	0.8746
UPCC [15]	0.7498	0.7915	0.8228	0.8467	0.8665	0.8823	0.8035	0.8416	0.8660	0.8848	0.9004	0.9130
IPCC [15]	0.7508	0.7949	0.8328	0.8578	0.8753	0.8893	0.7937	0.8233	0.8445	0.8663	0.8855	0.9015
UIPCC [15]	0.7517	0.7958	0.8333	0.8583	0.8759	0.8901	0.8032	0.8414	0.8663	0.8857	0.9017	0.9147
PMF [8, 16]	0.7312	0.7958	0.8310	0.8555	0.8740	0.8890	0.7988	0.8579	0.8864	0.9049	0.9183	0.9284
GreedyRank [18]	0.7222	0.7403	0.7545	0.7681	0.7824	0.7955	0.7735	0.7964	0.8120	0.8295	0.8474	0.8628
CloudRank [17]	0.7298	0.7569	0.7783	0.7978	0.8173	0.8346	0.7796	0.8096	0.8298	0.8494	0.8673	0.8817
NDCG@100												
Approach	Response Time						Throughput					
	5%	10%	15%	20%	25%	30%	5%	10%	15%	20%	25%	30%
UMEAN [15]	0.2668	0.3823	0.4648	0.5308	0.5873	0.6362	0.2857	0.4089	0.4993	0.5716	0.6328	0.6850
IMEAN [15]	0.7566	0.7907	0.8152	0.8342	0.8505	0.8646	0.8119	0.8351	0.8505	0.8636	0.8752	0.8857
UPCC [15]	0.7550	0.7918	0.8192	0.8409	0.8596	0.8751	0.8317	0.8677	0.8893	0.9046	0.9169	0.9269
IPCC [15]	0.7569	0.7940	0.8240	0.8466	0.8641	0.8789	0.8193	0.8444	0.8648	0.8852	0.9017	0.9147
UIPCC [15]	0.7578	0.7949	0.8247	0.8473	0.8648	0.8797	0.8313	0.8674	0.8895	0.9055	0.9182	0.9284
PMF [8, 16]	0.7409	0.7944	0.8253	0.8485	0.8666	0.8816	0.8265	0.8799	0.9055	0.9216	0.9328	0.9411
GreedyRank [18]	0.7327	0.7497	0.7631	0.7785	0.7947	0.8099	0.8017	0.8232	0.8379	0.8567	0.8752	0.8889
CloudRank [17]	0.7413	0.7677	0.7886	0.8085	0.8276	0.8446	0.8078	0.8355	0.8540	0.8740	0.8922	0.9053

2. REFERENCES

- [1] X. Chen, X. Liu, Z. Huang, and H. Sun. Regionknn: A scalable hybrid collaborative filtering algorithm for personalized web service recommendation. In *Proceedings of the IEEE International Conference on Web Services (ICWS)*, pages 9–16, 2010.
- [2] X. Chen, Z. Zheng, Q. Yu, and M. R. Lyu. Web service recommendation via exploiting location and qos information. *IEEE Trans. Parallel Distrib. Syst.*, 25(7):1913–1924, 2014.
- [3] Y. Koren. Factorization meets the neighborhood: a multifaceted collaborative filtering model. In *Proceedings of the 14th ACM SIGKDD International Conference on Knowledge Discovery and Data Mining (KDD)*, pages 426–434, 2008.
- [4] D. D. Lee and H. S. Seung. Algorithms for non-negative matrix factorization. In *Proceedings of the Annual Conference on Neural Information Processing Systems (NIPS)*, pages 556–562, 2000.
- [5] W. Lo, J. Yin, S. Deng, Y. Li, and Z. Wu. An extended matrix factorization approach for qos prediction in service selection. In *Proceedings of the 9th International Conference on Services Computing (SCC)*, pages 162–169, 2012.
- [6] Z. Z. J. X. Pinjia He, Jieming Zhu and M. R. Lyu. Location-based hierarchical matrix factorization for web service recommendation. In *Proceedings of the IEEE International Conference on Web Services (ICWS)*, 2014.
- [7] S. Rendle and L. Schmidt-Thieme. Pairwise interaction tensor factorization for personalized tag recommendation. In *Proceedings of the 3rd International Conference on Web Search and Web Data Mining (WSDM)*, pages 81–90, 2010.
- [8] R. Salakhutdinov and A. Mnih. Probabilistic matrix factorization. In *Proceedings of the 21st Annual Conference on Neural Information Processing Systems (NIPS)*, 2007.
- [9] M. Silic, G. Delac, and S. Srbljic. Prediction of atomic web services reliability based on k-means clustering. In *Proceedings of Joint Meeting of the European Software Engineering Conference and the ACM SIGSOFT Symposium on the Foundations of Software Engineering (ESEC/FSE)*, pages 70–80, 2013.
- [10] H. Sun, Z. Zheng, J. Chen, and M. R. Lyu. Personalized web service recommendation via normal recovery collaborative filtering. *IEEE T. Services Computing*, 6(4):573–579, 2013.
- [11] M. Tang, Y. Jiang, J. Liu, and X. F. Liu. Location-aware collaborative filtering for qos-based service recommendation. In *Proceedings of the 19th IEEE International Conference on Web Services (ICWS)*, pages 202–209, 2012.
- [12] J. Wu, L. Chen, Y. Feng, Z. Zheng, M. Zhou, and Z. Wu. Predicting quality of service for selection by neighborhood-based collaborative filtering. *IEEE T. Systems, Man, and Cybernetics: Systems*, 43(2):428–439, 2013.
- [13] W. Zhang, H. Sun, X. Liu, and X. Guo. Temporal qos-aware web service recommendation via non-negative tensor factorization. In *Proceedings of the 23rd International World Wide Web Conference (WWW)*, pages 585–596, 2014.
- [14] Y. Zhang, Z. Zheng, and M. R. Lyu. Exploring latent features for memory-based qos prediction in cloud computing. In *Proceedings of the 30th IEEE Symposium on Reliable Distributed Systems (SRDS)*, pages 1–10, 2011.
- [15] Z. Zheng, H. Ma, M. R. Lyu, and I. King. Qos-aware web service recommendation by collaborative filtering. *IEEE T. Services Computing*, 4(2):140–152, 2011.
- [16] Z. Zheng, H. Ma, M. R. Lyu, and I. King. Collaborative web service qos prediction via neighborhood integrated matrix factorization. *IEEE T. Services Computing*, 6(3):289–299, 2013.
- [17] Z. Zheng, X. Wu, Y. Zhang, M. R. Lyu, and J. Wang. Qos ranking prediction for cloud services. *IEEE Trans. Parallel Distrib. Syst.*, 24(6):1213–1222, 2013.
- [18] Z. Zheng, Y. Zhang, and M. R. Lyu. Cloudrank: A qos-driven component ranking framework for cloud computing. In *Proceedings of the 29th IEEE Symposium on Reliable Distributed Systems (SRDS)*, pages 184–193, 2010.
- [19] J. Zhu, P. He, Z. Zheng, and M. R. Lyu. Towards online, accurate, and scalable qos prediction for runtime service adaptation. In *Proceedings of the 34th IEEE International Conference on Distributed Computing Systems (ICDCS)*, pages 318–327, 2014.