

ADDITIONAL MATERIAL FOR: Role Mining Under a User-Distribution Cardinality Constraint

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Contents

1	Dataset Americas Large	3
1.1	Allowing Duplicate Roles	3
1.2	Duplicate Roles Forbidden - large μ value	5
1.3	Duplicate Roles Forbidden - small μ value	8
2	Dataset Americas Small	11
2.1	Allowing Duplicate Roles	11
2.2	Duplicate Roles Forbidden - large μ value	13
2.3	Duplicate Roles Forbidden - small μ value	16
3	Dataset Apj	19
3.1	Allowing Duplicate Roles	19
3.2	Duplicate Roles Forbidden - large μ value	21
3.3	Duplicate Roles Forbidden - small μ value	24
4	Dataset Customer	27
4.1	Allowing Duplicate Roles	27
4.2	Duplicate Roles Forbidden - large μ value	29
4.3	Duplicate Roles Forbidden - small μ value	32
5	Dataset Domino	35
5.1	Allowing Duplicate Roles	35
5.2	Duplicate Roles Forbidden - large μ value	37
5.3	Duplicate Roles Forbidden - small μ value	40
6	Dataset Emea	43
6.1	Allowing Duplicate Roles	43
6.2	Duplicate Roles Forbidden - large μ value	44
6.3	Duplicate Roles Forbidden - small μ value	47
7	Dataset Firewall 1	50
7.1	Allowing Duplicate Roles	50
7.2	Duplicate Roles Forbidden - large μ value	52
7.3	Duplicate Roles Forbidden - small μ value	55

8	Dataset Firewall 2	58
8.1	Allowing Duplicate Roles	58
8.2	Duplicate Roles Forbidden - large μ value	60
8.3	Duplicate Roles Forbidden - small μ value	63
9	Dataset Healthcare	66
9.1	Allowing Duplicate Roles	66
9.2	Duplicate Roles Forbidden - large μ value	68
9.3	Duplicate Roles Forbidden - small μ value	71

1 Dataset Americas Large

1.1 Allowing Duplicate Roles

μ	A ₁	A ₂	C ₁	C ₂	D ₁	D ₂	D ₃	D ₄	D ₅	D ₆	D ₇	D ₈	D ₉
278	425	431	442	426	407	439	425	621	425	441	2113	482	432
556	420	426	435	420	402	434	420	616	420	436	2108	477	427
834	418	425	433	418	401	433	418	615	419	435	2107	476	426
1111	417	424	432	417	400	432	417	614	418	434	2106	475	425
1389	417	423	432	417	399	431	417	613	417	433	2105	474	424
1667	416	423	431	416	399	431	416	613	417	433	2105	474	424
1944	416	423	431	416	399	431	416	613	417	433	2105	474	424
2222	416	423	431	416	399	431	416	613	417	433	2105	474	424
2500	416	423	431	416	399	431	416	613	417	433	2105	474	424
2777	416	422	431	416	398	430	416	612	416	432	2104	473	423
3055	415	422	430	415	398	430	415	612	416	432	2104	473	423
3333	415	422	430	415	398	430	415	612	416	432	2104	473	423

Table 1: Role-set size for dataset Americas Large

μ	A ₁	A ₂	C ₁	C ₂	D ₁	D ₂	D ₃	D ₄	D ₅	D ₆	D ₇	D ₈	D ₉
278	93524	101882	108536	93831	95613	107665	93367	90292	95293	107792	316123	106718	101684
556	93409	101767	108004	93453	95498	107550	93252	90177	95178	107677	316008	106603	101569
834	93363	101744	107852	93327	95475	107527	93206	90154	95155	107654	315985	106580	101546
1111	93340	101721	107776	93264	95452	107504	93183	90131	95132	107631	315962	106557	101523
1389	93340	101698	107776	93264	95429	107481	93183	90108	95109	107608	315939	106534	101500
1667	93317	101698	107700	93201	95429	107481	93160	90108	95109	107608	315939	106534	101500
1944	93317	101698	107700	93201	95429	107481	93160	90108	95109	107608	315939	106534	101500
2222	93317	101698	107700	93201	95429	107481	93160	90108	95109	107608	315939	106534	101500
2500	93317	101698	107700	93201	95429	107481	93160	90108	95109	107608	315939	106534	101500
2777	93317	101675	107700	93201	95406	107458	93160	90085	95086	107585	315916	106511	101477
3055	93294	101675	107624	93138	95406	107458	93137	90085	95086	107585	315916	106511	101477
3333	93294	101675	107624	93138	95406	107458	93137	90085	95086	107585	315916	106511	101477

Table 2: *WSC* values for dataset Americas Large

μ	A ₁	A ₂	C ₁	C ₂	D ₁	D ₂	D ₃	D ₄	D ₅	D ₆	D ₇	D ₈	D ₉
278	612	1220	655	680	193	193	164	204	180	5408	5301	235	195
556	664	1221	670	688	181	199	158	188	211	5385	5290	231	185
834	744	1276	657	737	224	198	188	194	181	5387	5215	259	186
1111	652	1130	642	655	180	189	172	181	182	5359	5133	214	204
1389	593	1159	622	687	187	185	160	219	177	5320	5215	228	181
1667	654	1241	611	656	214	188	159	187	213	5314	5247	227	182
1944	664	1179	659	677	185	213	161	183	179	5373	5145	296	185
2222	618	1298	669	691	181	190	195	185	211	5478	5173	230	232
2500	608	1276	660	675	182	193	154	227	179	5322	5223	231	186
2777	641	1285	615	666	218	188	156	184	215	5361	5250	230	184
3055	674	1222	673	675	183	217	155	185	177	5373	5160	308	185
3333	604	1271	674	683	181	186	181	185	178	5449	5124	242	222

Table 3: Execution times for dataset Americas Large

1.2 Duplicate Roles Forbidden - large μ value

M	V	278	556	834	1111	1389	1667	1944	2222	2500	2777	3055	3333	3485
WSC	Omin	96014	95616	95290	94989	94711	94409	94132	93854	93576	93299	93248	93248	93248
	Omax	110274	109876	109574	109273	108971	108693	108416	108138	107860	107585	107585	107585	107585
	Umin	95903	95505	95179	94878	94600	94298	94021	93743	93465	93188	93137	93137	93137
	Umax	110274	109876	109574	109273	108971	108693	108416	108138	107860	107585	107585	107585	107585
$ \mathcal{R} $	Omin	435	425	421	419	419	417	417	417	417	417	415	415	415
	Omax	450	440	438	436	434	434	434	434	434	432	432	432	432
	Umin	435	425	421	419	419	417	417	417	417	417	415	415	415
	Umax	450	440	438	436	434	434	434	434	434	432	432	432	432
$ \mathcal{UA} $	Omin	6493	6215	5937	5660	5382	5104	4827	4549	4272	3994	3967	3967	3967
	Omax	5958	5680	5402	5125	4847	4569	4292	4014	3736	3485	3485	3485	3485
	Umin	6604	6327	6048	5771	5493	5215	4938	4660	4382	4105	4078	4078	4078
	Umax	5958	5680	5402	5125	4847	4569	4292	4014	3736	3485	3485	3485	3485
$ \mathcal{PA} $	Omin	89086	88976	88932	88910	88910	88888	88888	88888	88886	88888	88866	88866	88866
	Omax	103866	103756	103734	103712	103690	103690	103690	103690	103690	103668	103668	103668	103668
	Umin	88864	88752	88710	88688	88688	88666	88666	88665	88666	88666	88644	88644	88644
	Umax	103866	103756	103734	103712	103690	103690	103690	103690	103690	103668	103668	103668	103668
$ \mathcal{DUPA} $	Omin	0	0	0	0	0	0	0	0	0	0	0	0	0
	Omax	0	0	0	0	0	0	0	0	0	0	0	0	0
	Umin	0	0	0	0	0	0	0	0	0	0	0	0	0
	Umax	0	0	0	0	0	0	0	0	0	0	0	0	0
time	Omin	784	722	704	714	701	705	703	706	710	730	737	729	782
	Omax	1292	1268	1266	1273	1272	1270	1274	1261	1264	1271	1267	1266	1305
	Umin	737	725	716	711	716	712	711	722	720	728	727	688	691
	Umax	1296	1282	1271	1286	1283	1263	1266	1266	1262	1264	1276	1276	1261

Table 4: Experiment's results for dataset Americas Large

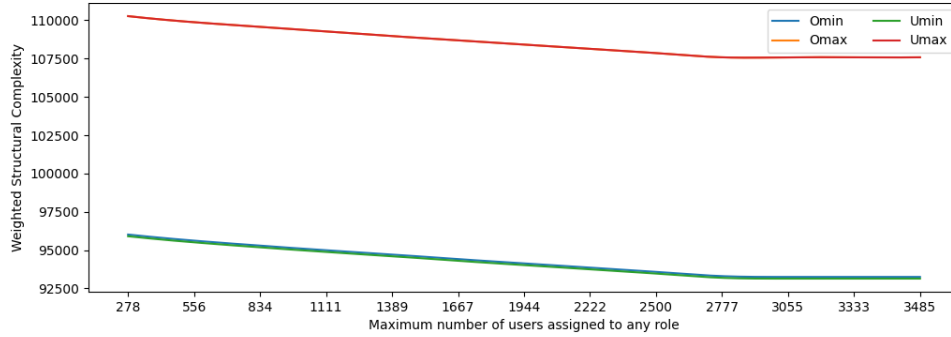


Figure 1: Dataset Americas Large: Weighted Structural Complexity

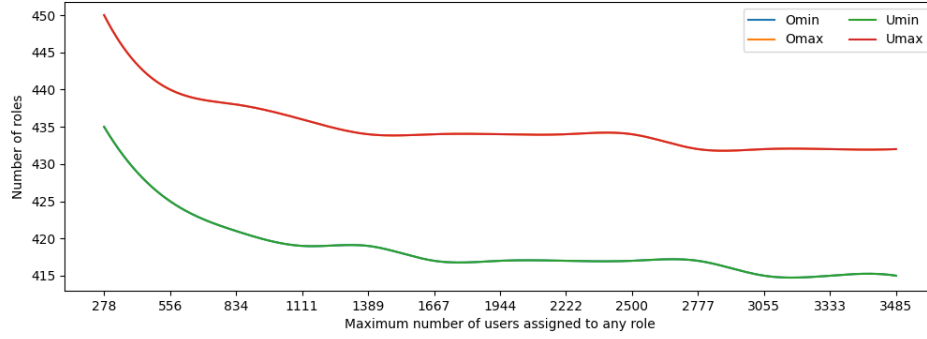


Figure 2: Dataset Americas Large: Number of roles

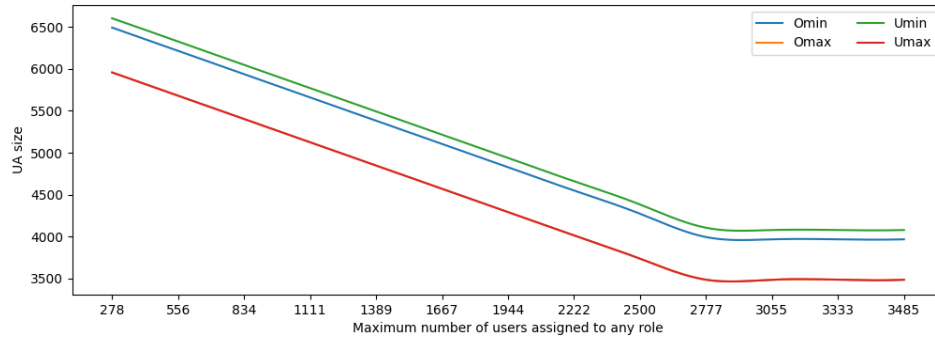


Figure 3: Dataset Americas Large: UA size

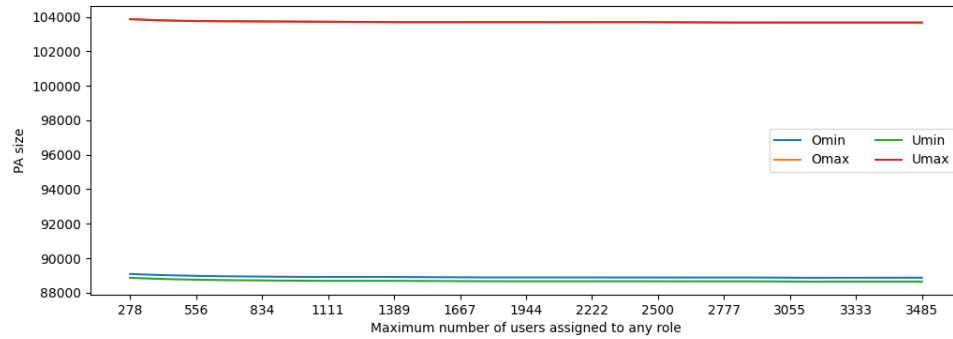


Figure 4: Dataset Americas Large: PA size

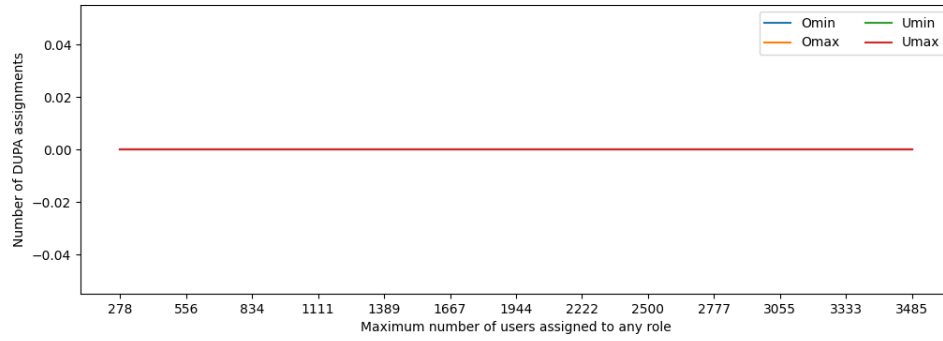


Figure 5: Dataset Americas Large: Number of DIPA assignments

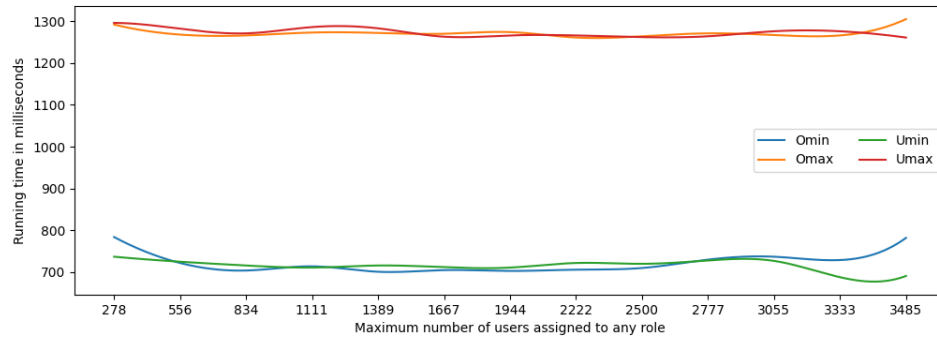


Figure 6: Dataset Americas Large: Running time in milliseconds

1.3 Duplicate Roles Forbidden - small μ value

M	V	1	2	3	4	5
WSC	Omin	198355	144319	126829	118545	113834
	Omax	198355	151033	135437	128546	124892
	Umin	198355	144214	126997	117875	113639
	Umax	198355	150988	135457	128548	124900
$ \mathcal{R} $	Omin	6532	3562	2513	1991	1675
	Omax	6532	3437	2403	1893	1598
	Umin	6532	3572	2539	2015	1701
	Umax	6532	3432	2403	1893	1598
$ \mathcal{UA} $	Omin	6532	6762	6815	6885	6929
	Omax	6532	6468	6418	6392	6373
	Umin	6532	6781	6900	7006	7058
	Umax	6532	6462	6414	6386	6371
$ \mathcal{PA} $	Omin	185291	133995	117500	109668	105229
	Omax	185291	141128	126615	120260	116920
	Umin	185291	133860	117557	108853	104879
	Umax	185291	141094	126639	120268	116930
$ \mathcal{DUPA} $	Omin	3	16	23	21	20
	Omax	3	7	10	3	2
	Umin	3	12	28	32	29
	Umax	3	2	1	0	0
time	Omin	12076	5625	4175	3477	2411
	Omax	11368	5778	4093	3497	2605
	Umin	11349	6036	4156	3366	2405
	Umax	11919	5291	4606	3297	2599

Table 5: Experiment's results for dataset Americas Large

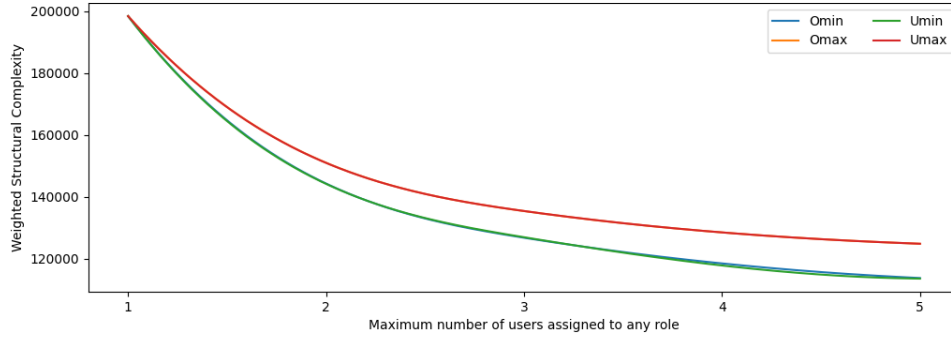


Figure 7: Dataset Americas Large: Weighted Structural Complexity

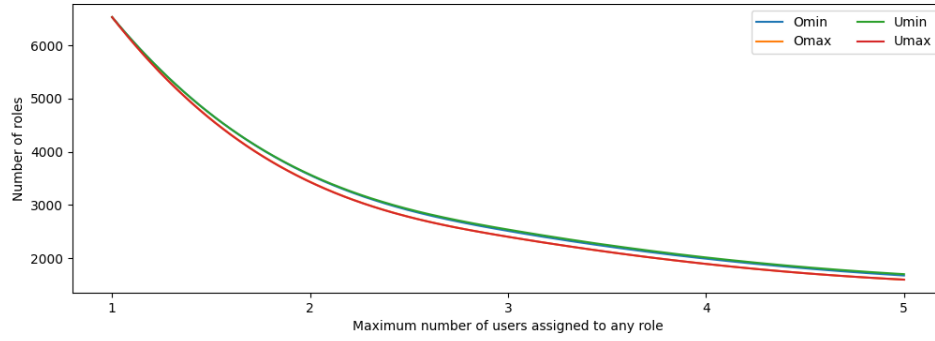


Figure 8: Dataset Americas Large: Number of roles

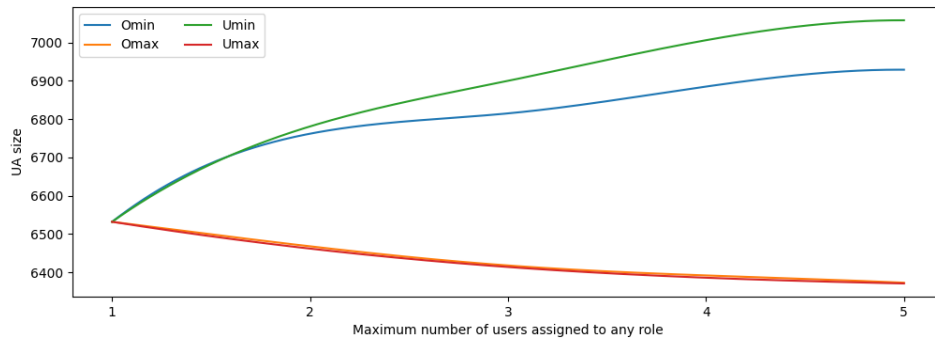


Figure 9: Dataset Americas Large: UA size

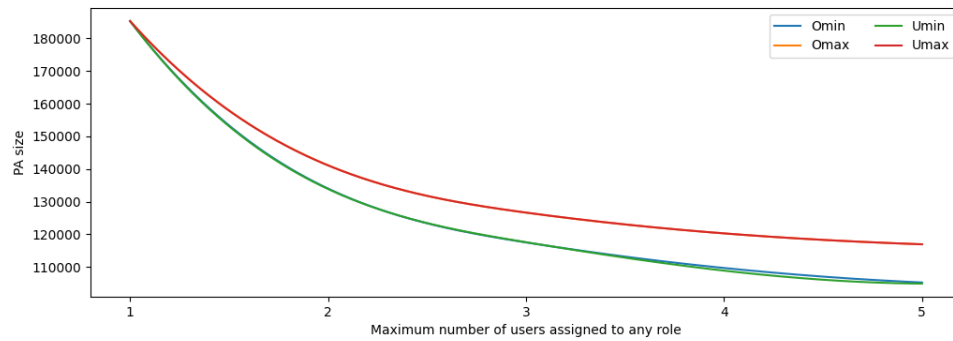


Figure 10: Dataset Americas Large: PA size

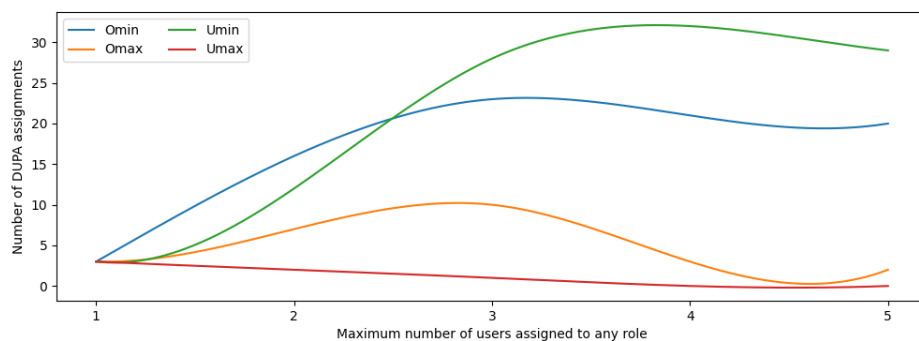


Figure 11: Dataset Americas Large: Number of DUPA assignments

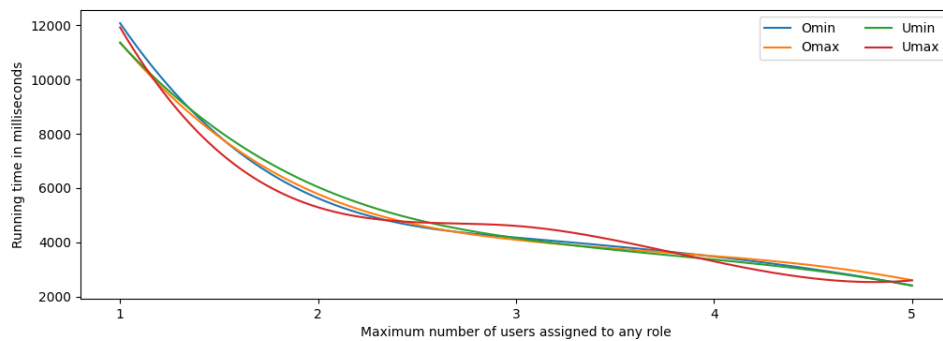


Figure 12: Dataset Americas Large: Running time in milliseconds

2 Dataset Americas Small

2.1 Allowing Duplicate Roles

μ	A ₁	A ₂	C ₁	C ₂	D ₁	D ₂	D ₃	D ₄	D ₅	D ₆	D ₇	D ₈	D ₉
281	222	215	240	219	187	234	217	213	207	268	420	204	240
562	217	210	231	212	182	229	212	208	202	263	415	199	225
843	215	209	228	210	181	228	210	207	201	262	414	198	222
1124	214	208	227	209	180	227	209	206	200	261	413	197	219
1405	214	207	227	209	179	226	209	205	199	260	412	196	216
1686	213	207	226	208	179	226	208	205	199	260	412	196	216
1967	213	207	226	208	179	226	208	205	199	260	412	196	216
2248	213	207	226	208	179	226	208	205	199	260	412	196	216
2529	213	207	226	208	179	226	208	205	199	260	412	196	216
2809	213	206	226	208	178	225	208	204	198	259	411	195	213
3090	212	206	225	207	178	225	207	204	198	259	411	195	213
3371	212	206	225	207	178	225	207	204	198	259	411	195	213

Table 6: Role-set size for dataset Americas Small

μ	A ₁	A ₂	C ₁	C ₂	D ₁	D ₂	D ₃	D ₄	D ₅	D ₆	D ₇	D ₈	D ₉
281	11092	15549	24885	12700	11286	21712	10680	13627	14235	25695	30197	14826	22024
562	10977	15434	23724	12091	11171	21597	10565	13512	14120	25580	30082	14711	21899
843	10931	15411	23337	11917	11148	21574	10519	13489	14097	25557	30059	14688	21874
1124	10908	15388	23208	11830	11125	21551	10496	13466	14074	25534	30036	14665	21849
1405	10908	15365	23208	11830	11102	21528	10496	13443	14051	25511	30013	14642	21824
1686	10885	15365	23079	11743	11102	21528	10473	13443	14051	25511	30013	14642	21824
1967	10885	15365	23079	11743	11102	21528	10473	13443	14051	25511	30013	14642	21824
2248	10885	15365	23079	11743	11102	21528	10473	13443	14051	25511	30013	14642	21824
2529	10885	15365	23079	11743	11102	21528	10473	13443	14051	25511	30013	14642	21824
2809	10885	15342	23079	11743	11079	21505	10473	13420	14028	25488	29990	14619	21799
3090	10862	15342	22950	11656	11079	21505	10450	13420	14028	25488	29990	14619	21799
3371	10862	15342	22950	11656	11079	21505	10450	13420	14028	25488	29990	14619	21799

Table 7: *WSC* values for dataset Americas Small

μ	A ₁	A ₂	C ₁	C ₂	D ₁	D ₂	D ₃	D ₄	D ₅	D ₆	D ₇	D ₈	D ₉
281	340	411	362	451	88	112	86	94	96	2747	2668	111	91
562	362	401	320	443	88	86	104	94	93	2695	2704	106	90
843	322	441	329	433	88	87	85	92	111	2694	2684	107	116
1124	325	404	355	410	88	105	84	93	94	2722	2658	107	92
1405	319	424	314	423	90	87	84	114	95	2679	2668	136	91
1686	308	401	353	383	116	87	84	93	92	2722	2715	107	92
1967	338	401	312	414	90	88	103	93	94	2687	2711	107	90
2248	303	439	317	417	86	86	88	94	114	2694	2667	105	111
2529	299	404	346	373	94	104	84	92	91	2738	2670	106	91
2809	324	403	323	437	98	90	88	113	96	2782	2716	140	87
3090	305	408	345	393	88	86	85	95	95	2801	2697	104	108
3371	303	407	338	365	90	109	87	93	95	2704	2717	110	87

Table 8: Execution times for dataset Americas Small

2.2 Duplicate Roles Forbidden - large μ value

M	V	281	562	843	1124	1405	1686	1967	2248	2529	2809	3090	3371	3477
WSC	Omin	12949	12549	12220	11915	11634	11329	11048	10767	10486	10206	10134	10134	10134
	Omax	28174	27773	27468	27163	26858	26577	26296	26015	25734	25488	25488	25488	25488
	Umin	13203	13027	12474	12169	11885	11583	11302	11021	10740	10460	10388	10388	10388
	Umax	28174	27773	27468	27163	26858	26577	26296	26015	25734	25488	25488	25488	25488
$ \mathcal{R} $	Omin	216	206	202	200	200	198	198	198	198	198	196	196	196
	Omax	277	267	265	263	261	261	261	261	261	259	259	259	259
	Umin	227	217	213	211	210	209	209	209	209	209	207	207	207
	Umax	277	267	265	263	261	261	261	261	261	259	259	259	259
$ \mathcal{UA} $	Omin	8534	8253	7972	7691	7410	7129	6848	6567	6286	6006	5958	5958	5958
	Omax	5947	5666	5385	5104	4823	4542	4261	3980	3699	3477	3477	3477	3477
	Umin	9718	9661	9156	8875	8592	8313	8032	7751	7470	7190	7142	7142	7142
	Umax	5947	5666	5385	5104	4823	4542	4261	3980	3699	3477	3477	3477	3477
$ \mathcal{PA} $	Omin	4199	4090	4046	4024	4024	4002	4002	4002	4002	4002	3980	3980	3980
	Omax	21950	21840	21818	21796	21774	21774	21774	21774	21774	21752	21752	21752	21752
	Umin	3258	3148	3105	3083	3082	3061	3061	3061	3061	3061	3039	3039	3039
	Umax	21950	21840	21818	21796	21774	21774	21774	21774	21774	21752	21752	21752	21752
$ \mathcal{DUPA} $	Omin	0	0	0	0	0	0	0	0	0	0	0	0	0
	Omax	0	0	0	0	0	0	0	0	0	0	0	0	0
	Umin	0	0	0	0	1	0	0	0	0	0	0	0	0
	Umax	0	0	0	0	0	0	0	0	0	0	0	0	0
time	Omin	388	354	353	350	356	339	340	340	341	341	339	336	333
	Omax	682	672	660	653	657	653	655	653	654	651	653	652	660
	Umin	408	386	373	365	368	360	353	358	349	344	347	343	334
	Umax	699	681	671	664	658	682	662	659	666	658	658	659	658

Table 9: Experiment's results for dataset Americas Small

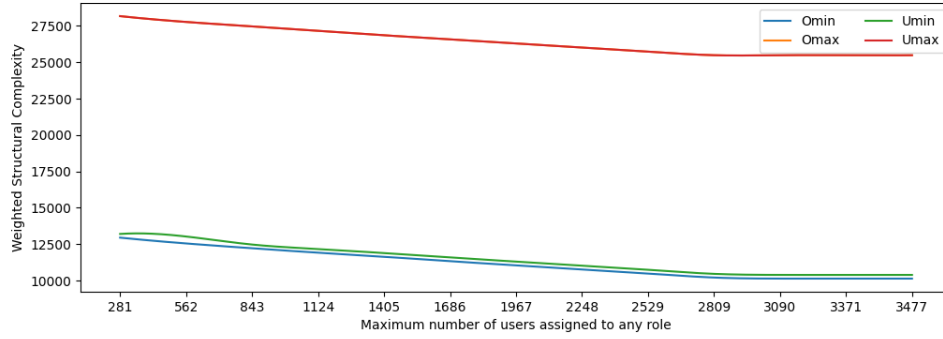


Figure 13: Dataset Americas Small: Weighted Structural Complexity

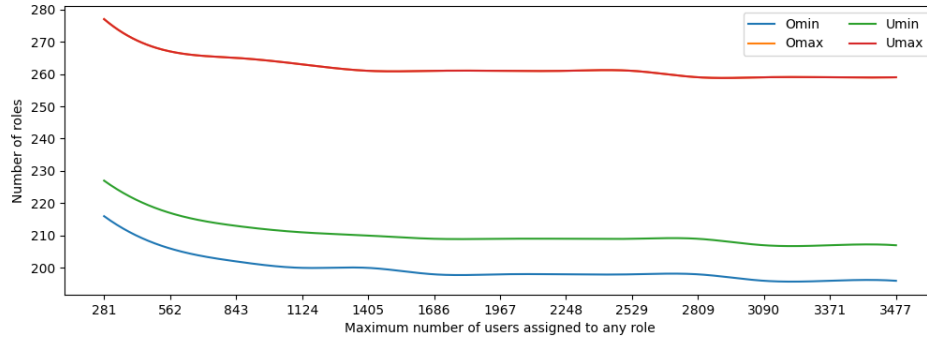


Figure 14: Dataset Americas Small: Number of roles

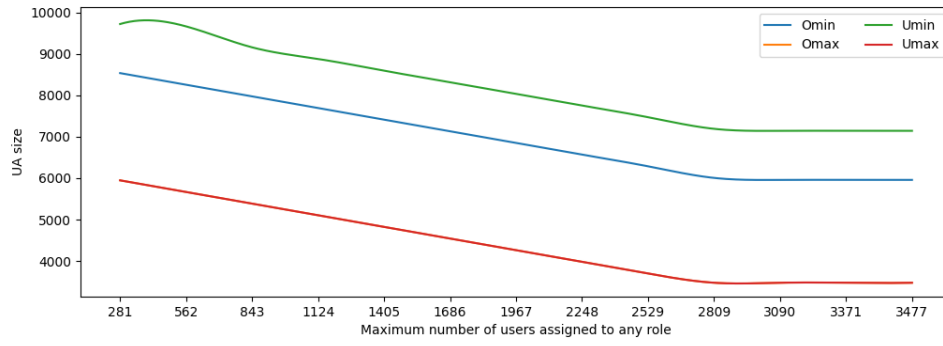


Figure 15: Dataset Americas Small: UA size

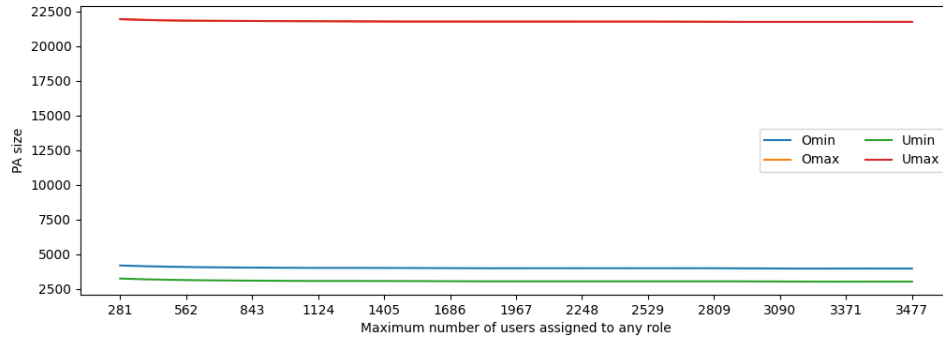


Figure 16: Dataset Americas Small: PA size

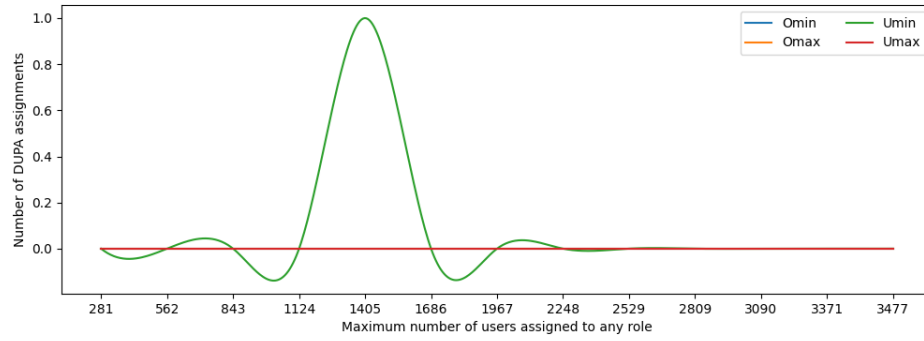


Figure 17: Dataset Americas Small: Number of DUPA assignments

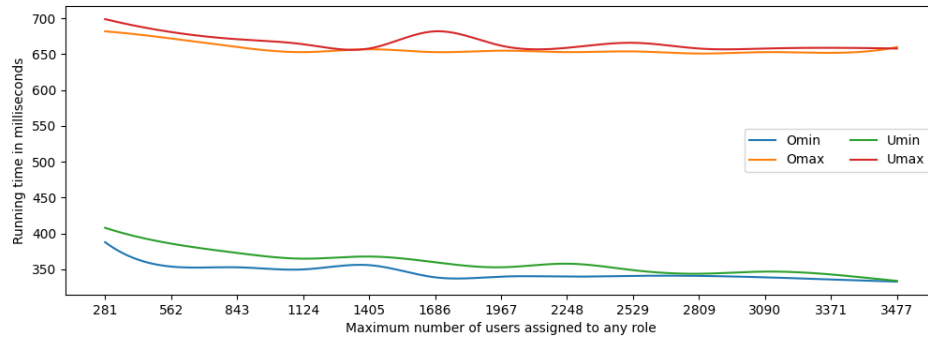


Figure 18: Dataset Americas Small: Running time in milliseconds

2.3 Duplicate Roles Forbidden - small μ value

M	V	1	2	3	4	5
WSC	Omin	118273	68435	50122	40620	35380
	Omax	118270	70765	56747	47865	43684
	Umin	118275	66952	49548	40032	34617
	Umax	118272	71402	55597	47835	43595
$ \mathcal{R} $	Omin	6588	3699	2592	2027	1679
	Omax	6587	3436	2704	1801	1474
	Umin	6588	3766	2658	2087	1728
	Umax	6587	3387	2313	1774	1459
$ \mathcal{UA} $	Omin	6588	7308	7599	7813	7976
	Omax	6587	6653	7666	6541	6474
	Umin	6588	7433	7761	8011	8194
	Umax	6587	6565	6505	6444	6405
$ \mathcal{PA} $	Omin	105097	57426	39930	30779	25725
	Omax	105096	60675	46376	39521	35735
	Umin	105098	55752	39128	29934	24695
	Umax	105097	61449	46778	39616	35730
$ \mathcal{DUPA} $	Omin	107	128	139	147	144
	Omax	108	108	119	97	92
	Umin	106	125	123	131	124
	Umax	108	99	91	82	76
time	Omin	11315	6474	4195	2904	2245
	Omax	11879	5808	4188	2900	2050
	Umin	13040	6865	4979	3920	2339
	Umax	11598	5327	4208	3152	2116

Table 10: Experiment's results for dataset Americas Small

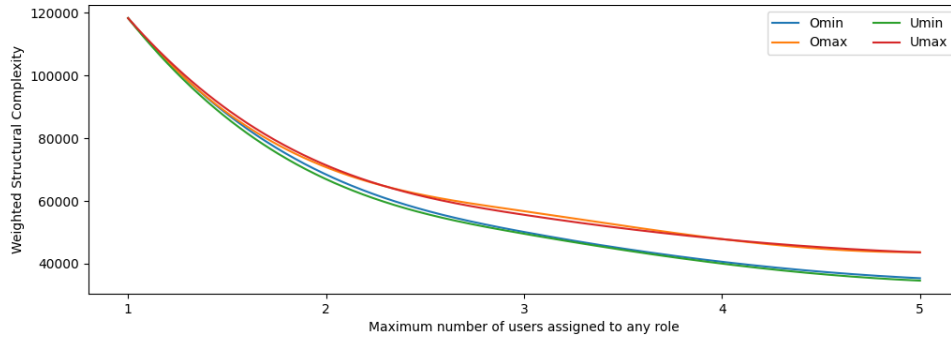


Figure 19: Dataset Americas Small: Weighted Structural Complexity

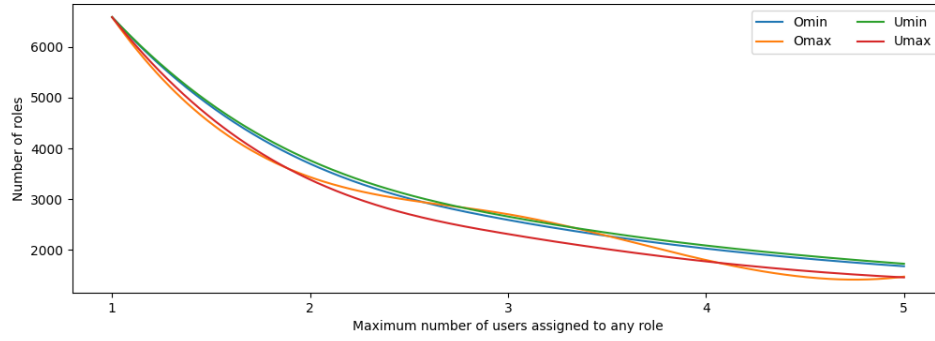


Figure 20: Dataset Americas Small: Number of roles

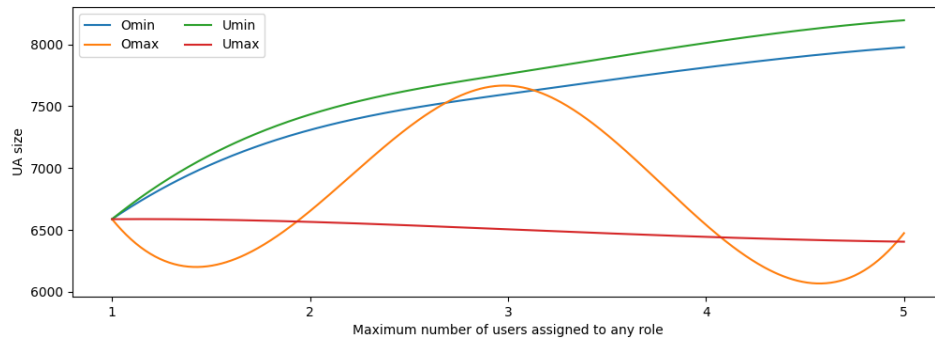


Figure 21: Dataset Americas Small: UA size

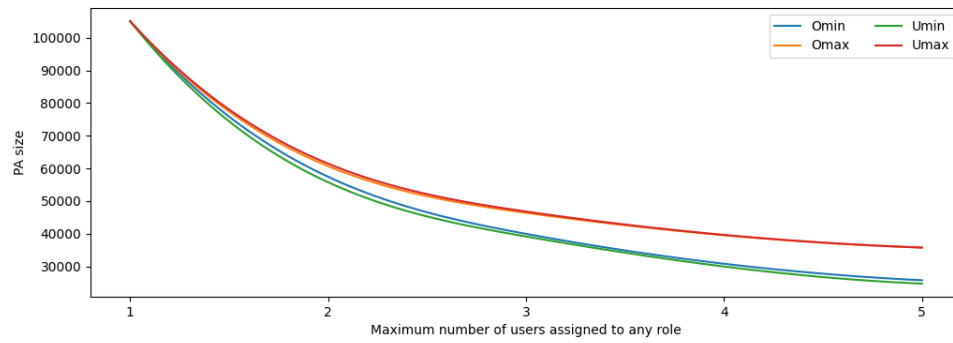


Figure 22: Dataset Americas Small: PA size

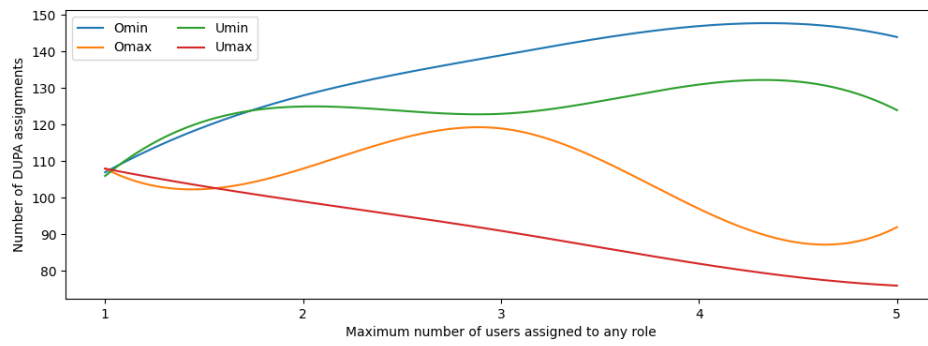


Figure 23: Dataset Americas Small: Number of DUPA assignments

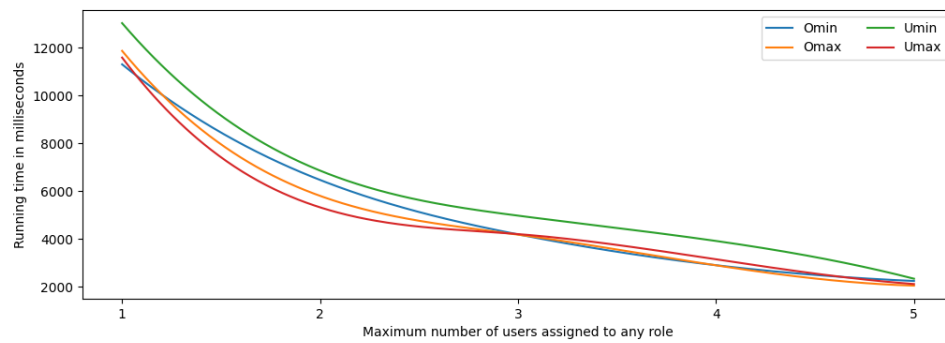


Figure 24: Dataset Americas Small: Running time in milliseconds

3 Dataset Apj

3.1 Allowing Duplicate Roles

μ	A ₁	A ₂	C ₁	C ₂	D ₁	D ₂	D ₃	D ₄	D ₅	D ₆	D ₇	D ₈	D ₉
28	489	468	630	581	477	484	485	485	468	571	600	471	485
56	466	458	573	510	460	477	464	469	456	565	591	463	464
84	462	457	552	472	458	476	461	467	455	564	590	462	460
112	458	457	532	460	455	476	458	467	454	564	590	462	459
139	457	456	487	457	454	475	457	467	454	564	589	462	458
167	456	456	478	457	454	475	456	465	454	564	589	461	458
195	456	456	477	456	454	475	456	465	453	564	589	461	458
223	456	456	476	456	454	475	456	465	453	564	589	461	457
251	456	456	476	456	454	475	456	465	453	564	589	461	456
278	456	456	476	456	453	475	456	465	453	564	589	461	456
306	455	456	475	455	453	475	455	465	453	564	589	461	456
334	455	456	475	455	453	475	455	465	453	564	589	461	456

Table 11: Role-set size for dataset Apj

μ	A ₁	A ₂	C ₁	C ₂	D ₁	D ₂	D ₃	D ₄	D ₅	D ₆	D ₇	D ₈	D ₉
28	5278	5270	9364	8472	4945	5485	5157	5563	5268	6150	5885	5253	5847
56	5206	5232	9929	8051	4881	5464	5086	5506	5227	6134	5848	5227	5789
84	5191	5227	10181	6269	4872	5459	5071	5498	5222	6129	5843	5222	5778
112	5121	5227	9431	5471	4857	5459	5059	5498	5217	6129	5843	5222	5774
139	5062	5222	7437	5256	4852	5454	5054	5498	5217	6129	5838	5222	5772
167	5169	5222	6772	5358	4852	5454	5049	5490	5217	6129	5838	5217	5772
195	5141	5222	6656	5248	4852	5454	5049	5490	5212	6129	5838	5217	5772
223	5113	5222	6517	5234	4852	5454	5049	5490	5212	6129	5838	5217	5768
251	5085	5222	6526	5218	4852	5454	5049	5490	5212	6129	5838	5217	5766
278	5058	5222	6540	5199	4847	5454	5049	5490	5212	6129	5838	5217	5766
306	5045	5222	6391	5115	4847	5454	5044	5490	5212	6129	5838	5217	5766
334	5045	5222	6391	5115	4847	5454	5044	5490	5212	6129	5838	5217	5766

Table 12: *WSC* values for dataset Apj

μ	A ₁	A ₂	C ₁	C ₂	D ₁	D ₂	D ₃	D ₄	D ₅	D ₆	D ₇	D ₈	D ₉
28	107	174	172	170	37	30	29	29	28	52	65	31	29
56	100	176	149	160	39	31	28	28	28	49	45	32	45
84	100	171	141	158	28	28	39	31	28	48	45	30	28
112	99	186	136	151	29	29	28	28	38	52	45	31	28
139	97	179	134	165	28	29	28	31	29	49	61	31	29
167	98	172	137	153	28	41	28	29	28	49	47	33	41
195	103	172	128	150	28	29	28	41	28	48	45	30	28
223	100	188	126	150	28	29	28	28	28	62	45	30	28
251	97	178	130	164	27	29	28	30	29	49	45	43	29
278	100	169	131	148	27	39	30	28	27	48	46	33	29
306	110	171	125	151	27	29	28	40	31	49	45	30	28
334	100	171	149	149	29	29	27	28	27	61	46	30	28

Table 13: Execution times for dataset Apj

3.2 Duplicate Roles Forbidden - large μ value

M	V	28	56	84	112	139	167	195	223	251	278	306	334	2044
WSC	Omin	5363	5519	5295	5235	5191	5157	5129	5102	5074	5046	5039	5039	5039
	Omax	6188	6152	6129	6129	6129	6129	6129	6129	6129	6129	6129	6129	6129
	Umin	5343	5489	5438	5240	5195	5168	5140	5112	5084	5057	5044	5044	5044
	Umax	6188	6152	6129	6129	6129	6129	6129	6129	6129	6129	6129	6129	6129
$ \mathcal{R} $	Omin	486	471	464	459	457	455	455	455	456	455	454	454	454
	Omax	570	566	564	564	564	564	564	564	564	564	564	564	564
	Umin	484	472	466	460	458	456	456	456	456	456	455	455	455
	Umax	570	566	564	564	564	564	564	564	564	564	564	564	564
$ \mathcal{UA} $	Omin	3394	3623	3411	3370	3331	3302	3274	3246	3219	3191	3188	3188	3188
	Omax	2087	2061	2044	2044	2044	2044	2044	2044	2044	2044	2044	2044	2044
	Umin	3382	3592	3557	3379	3341	3321	3293	3265	3237	3210	3198	3198	3198
	Umax	2087	2061	2044	2044	2044	2044	2044	2044	2044	2044	2044	2044	2044
$ \mathcal{PA} $	Omin	1482	1425	1420	1406	1402	1399	1399	1399	1399	1399	1397	1397	1397
	Omax	3531	3525	3521	3521	3521	3521	3521	3521	3521	3521	3521	3521	3521
	Umin	1476	1425	1414	1400	1396	1391	1391	1391	1391	1391	1391	1391	1391
	Umax	3531	3525	3521	3521	3521	3521	3521	3521	3521	3521	3521	3521	3521
$ \mathcal{DUPA} $	Omin	351	9	0	0	0	0	0	0	0	0	0	0	0
	Omax	26	0	0	0	0	0	0	0	0	0	0	0	0
	Umin	388	31	32	6	9	0	0	0	0	0	0	0	0
	Umax	26	0	0	0	0	0	0	0	0	0	0	0	0
time	Omin	191	150	148	144	145	140	143	142	140	144	138	141	142
	Omax	270	256	254	255	256	256	249	253	252	256	253	253	256
	Umin	185	146	144	140	141	141	139	136	146	139	138	135	139
	Umax	262	259	255	256	255	253	252	253	249	252	253	251	250

Table 14: Experiment's results for dataset Apj

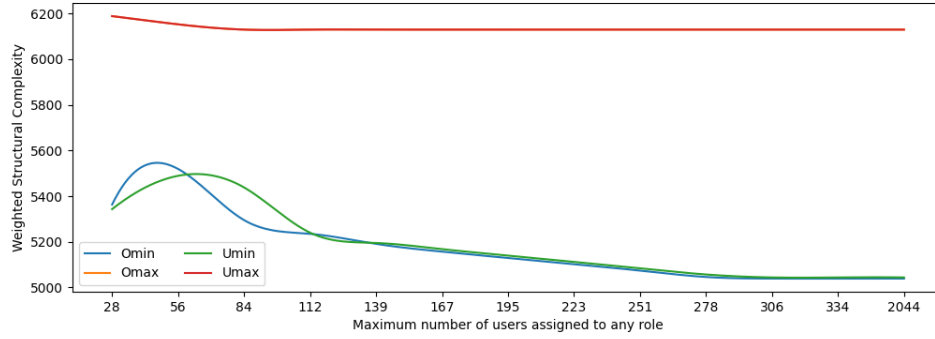


Figure 25: Dataset Apj: Weighted Structural Complexity

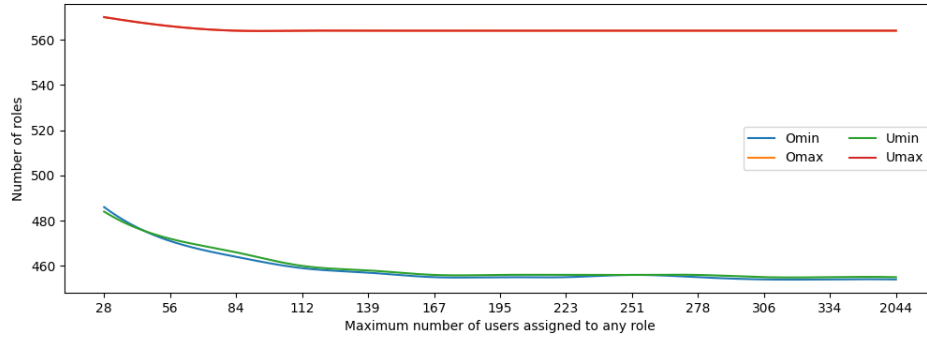


Figure 26: Dataset Apj: Number of roles

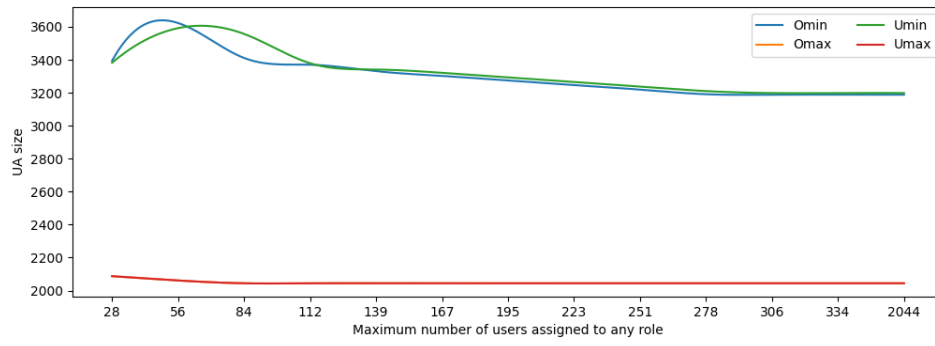


Figure 27: Dataset Apj: UA size

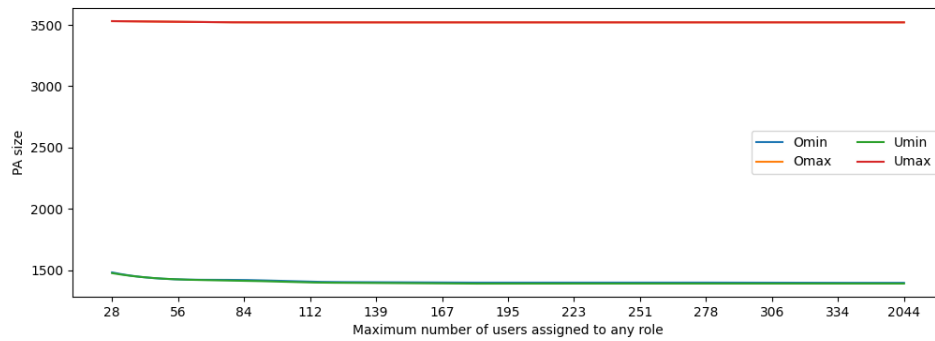


Figure 28: Dataset Apj: PA size

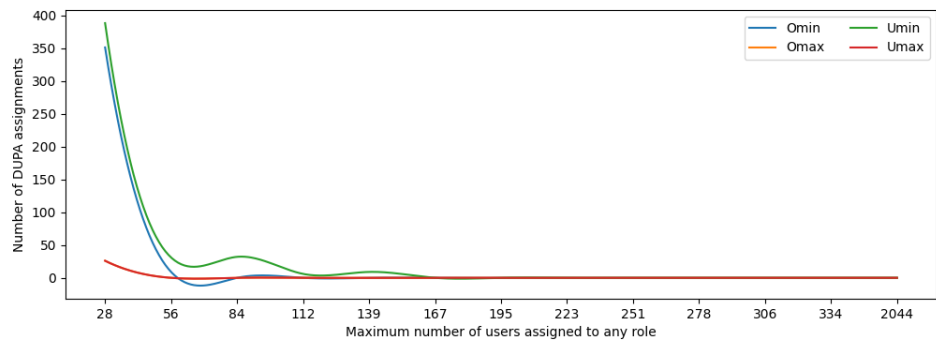


Figure 29: Dataset Apj: Number of DUPA assignments

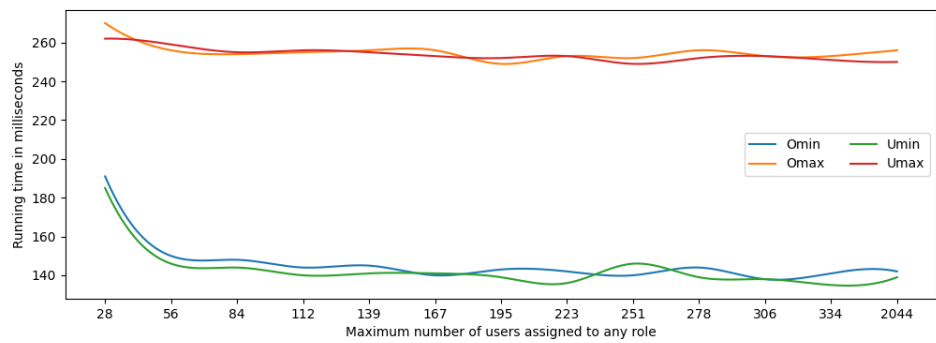


Figure 30: Dataset Apj: Running time in milliseconds

3.3 Duplicate Roles Forbidden - small μ value

M	V	1	2	3	4	5
WSC	Omin	7310	5156	5014	4584	4568
	Omax	7362	6040	6033	5688	5790
	Umin	7305	5081	4868	4520	4511
	Umax	7366	6100	6058	5716	5806
$ \mathcal{R} $	Omin	1111	729	703	593	581
	Omax	1120	782	764	627	623
	Umin	1109	743	710	600	575
	Umax	1120	789	761	629	625
$ \mathcal{UA} $	Omin	1111	1356	1589	1775	1955
	Omax	1120	1234	1377	1428	1541
	Umin	1109	1376	1629	1784	1928
	Umax	1120	1248	1370	1440	1549
$ \mathcal{PA} $	Omin	5088	3070	2721	2216	2031
	Omax	5122	4024	3891	3632	3626
	Umin	5086	2961	2528	2135	2007
	Umax	5124	4063	3925	3645	3632
$ \mathcal{DUPA} $	Omin	1752	1888	1806	1674	1531
	Omax	1718	1454	1231	1004	845
	Umin	1754	1913	1820	1689	1549
	Umax	1716	1422	1217	999	834
time	Omin	697	643	577	708	632
	Omax	897	568	566	418	550
	Umin	636	549	584	567	569
	Umax	843	524	662	603	450

Table 15: Experiment's results for dataset Apj

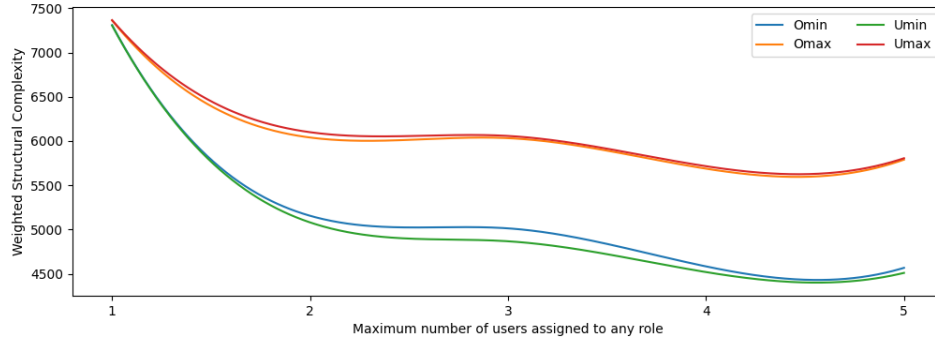


Figure 31: Dataset Apj: Weighted Structural Complexity

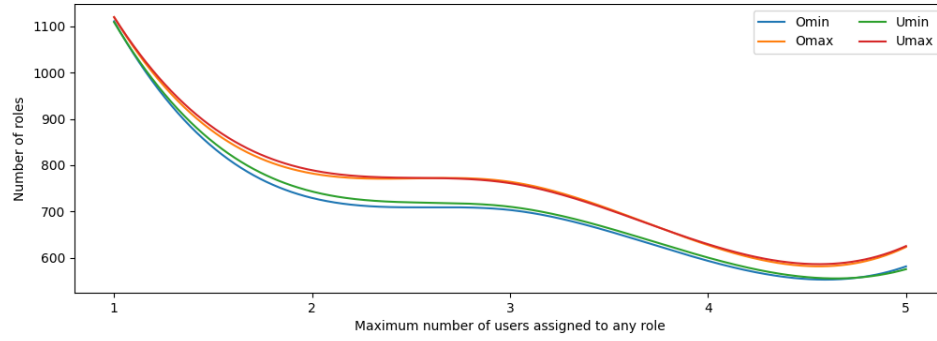


Figure 32: Dataset Apj: Number of roles

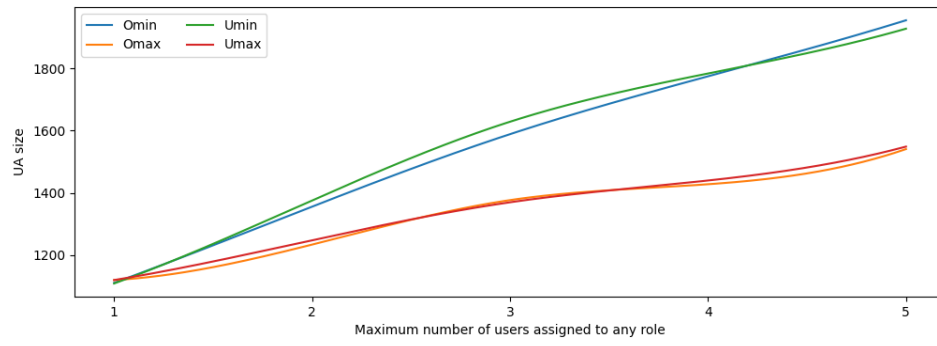


Figure 33: Dataset Apj: UA size

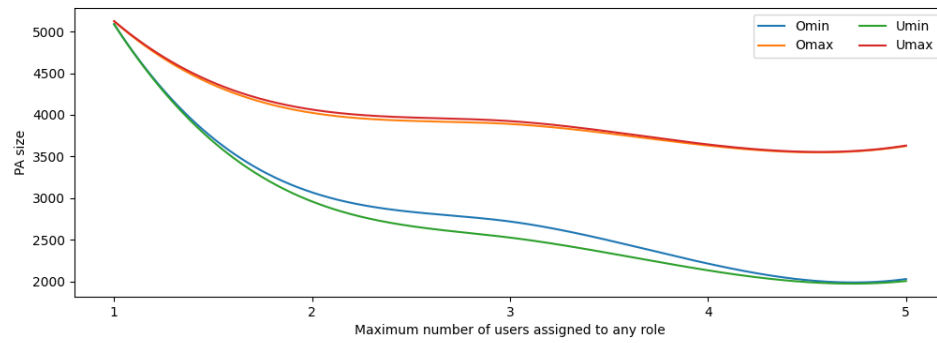


Figure 34: Dataset Apj: PA size

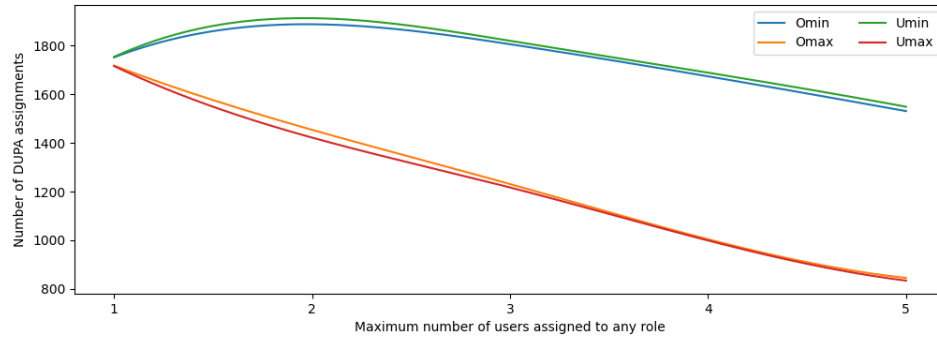


Figure 35: Dataset Apj: Number of DUPA assignments

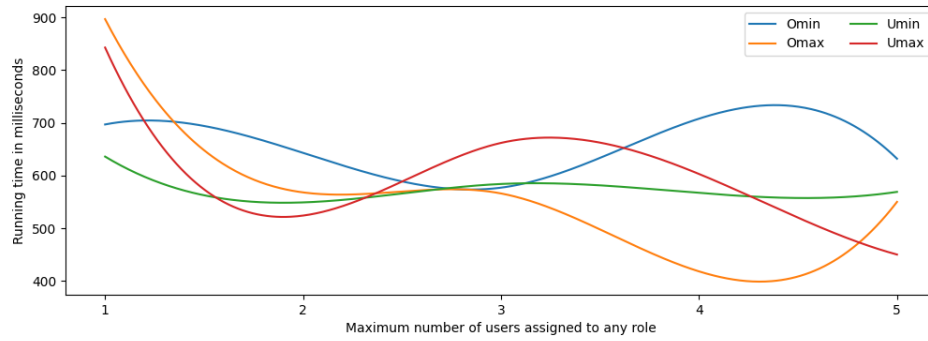


Figure 36: Dataset Apj: Running time in milliseconds

4 Dataset Customer

4.1 Allowing Duplicate Roles

μ	A ₁	A ₂	C ₁	C ₂	D ₁	D ₂	D ₃	D ₄	D ₅	D ₆	D ₇	D ₈	D ₉
419	338	336	1972	542	-	1188	338	336	336	5655	13041	351	338
837	295	294	1614	296	-	1163	295	294	294	5655	13041	315	295
1256	285	285	1464	285	-	1159	285	285	285	5655	13041	306	285
1674	283	282	1364	283	-	1157	283	282	282	5655	13041	303	283
2092	280	280	1231	281	-	1157	280	280	280	5655	13041	301	280
2511	279	279	1160	279	-	1155	279	279	279	5655	13041	300	279
2929	279	279	1158	279	-	1155	279	279	279	5655	13041	300	279
3348	278	278	1156	278	-	1154	278	278	278	5655	13041	299	278
3766	277	277	1155	277	-	1154	277	277	277	5655	13041	298	277
4184	276	276	1154	276	-	1154	276	276	276	5655	13041	297	276
4603	276	276	1154	276	-	1154	276	276	276	5655	13041	297	276
5021	276	276	1154	276	-	1154	276	276	276	5655	13041	297	276

Table 16: Role-set size for dataset Customer

μ	A ₁	A ₂	C ₁	C ₂	D ₁	D ₂	D ₃	D ₄	D ₅	D ₆	D ₇	D ₈	D ₉
419	46102	45445	282474	135511	-	42324	46102	45447	45582	49761	110578	43514	46102
837	46016	45368	304208	48517	-	42274	46016	45363	45498	49761	110578	43441	46016
1256	45996	45350	318740	46189	-	42266	45996	45345	45480	49761	110578	43423	45996
1674	45992	45344	302375	46109	-	42262	45992	45339	45474	49761	110578	43417	45992
2092	45986	45340	146489	46076	-	42262	45986	45335	45470	49761	110578	43413	45986
2511	45984	45338	66089	46067	-	42258	45984	45333	45468	49761	110578	43411	45984
2929	45984	45338	62418	46023	-	42258	45984	45333	45468	49761	110578	43411	45984
3348	45982	45336	59134	45998	-	42256	45982	45331	45466	49761	110578	43409	45982
3766	45980	45334	57261	45983	-	42256	45980	45329	45464	49761	110578	43407	45980
4184	45978	45332	55184	45978	-	42256	45978	45327	45462	49761	110578	43405	45978
4603	45978	45332	55184	45978	-	42256	45978	45327	45462	49761	110578	43405	45978
5021	45978	45332	55184	45978	-	42256	45978	45327	45462	49761	110578	43405	45978

Table 17: WSC values for dataset Customer

μ	A ₁	A ₂	C ₁	C ₂	D ₁	D ₂	D ₃	D ₄	D ₅	D ₆	D ₇	D ₈	D ₉
419	574	648	4300	2138	-	273	198	236	241	16964	17031	256	254
837	488	575	2915	1434	-	238	243	189	230	16983	17055	243	237
1256	446	557	2240	1349	-	251	192	221	199	17044	17000	252	257
1674	446	572	1812	1256	-	232	242	188	243	16951	17444	242	230
2092	462	531	1245	1266	-	211	232	192	220	16933	17299	354	195
2511	482	525	1028	1097	-	254	187	233	189	17049	17212	335	242
2929	436	581	967	1075	-	209	241	186	219	16956	17415	352	197
3348	475	528	986	1060	-	251	185	220	233	17001	17124	247	252
3766	440	564	952	935	-	245	186	221	239	17962	17190	248	240
4184	460	558	905	932	-	208	225	189	213	17037	17270	352	196
4603	472	525	913	952	-	244	183	219	232	17089	17126	262	243
5021	432	552	903	928	-	206	230	186	215	17095	17059	358	197

Table 18: Execution times for dataset Customer

4.2 Duplicate Roles Forbidden - large μ value

M	V	419	837	1256	1674	2092	2511	2929	3348	3766	4184	4603	5021	10021
WSC	Omin	38332	40245	41326	42037	43010	43778	44788	45218	45531	45944	45944	45944	45944
	Omax	49761	49761	49761	49761	49761	49761	49761	49761	49761	49761	49761	49761	49761
	Umin	35418	38682	40173	41354	42556	43421	44269	45034	45561	45978	45978	45978	45978
	Umax	49761	49761	49761	49761	49761	49761	49761	49761	49761	49761	49761	49761	49761
$ \mathcal{R} $	Omin	437	334	314	310	302	295	288	283	280	279	279	279	279
	Omax	5655	5655	5655	5655	5655	5655	5655	5655	5655	5655	5655	5655	5655
	Umin	408	299	287	287	282	279	279	277	276	276	276	276	276
	Umax	5655	5655	5655	5655	5655	5655	5655	5655	5655	5655	5655	5655	5655
$ \mathcal{UA} $	Omin	37248	39497	40640	41364	42364	43155	44188	44634	44957	45375	45375	45375	45375
	Omax	10021	10021	10021	10021	10021	10021	10021	10021	10021	10021	10021	10021	10021
	Umin	34446	38048	39577	40757	41977	42855	43704	44477	45007	45425	45425	45425	45425
	Umax	10021	10021	10021	10021	10021	10021	10021	10021	10021	10021	10021	10021	10021
$ \mathcal{PA} $	Omin	647	414	372	363	344	328	312	301	294	290	290	290	290
	Omax	34085	34085	34085	34085	34085	34085	34085	34085	34085	34085	34085	34085	34085
	Umin	564	335	309	310	297	287	286	280	278	277	277	277	277
	Umax	34085	34085	34085	34085	34085	34085	34085	34085	34085	34085	34085	34085	34085
$ \mathcal{DUPA} $	Omin	3022	2266	2061	2155	1728	1462	973	698	404	0	0	0	0
	Omax	0	0	0	0	0	0	0	0	0	0	0	0	0
	Umin	6333	4107	3381	3052	2326	1905	1462	915	417	0	0	0	0
	Umax	0	0	0	0	0	0	0	0	0	0	0	0	0
time	Omin	6300	4397	3368	3085	2234	1736	2058	1031	1022	876	726	795	699
	Omax	21026	22149	21389	21358	21419	26938	24439	21646	24830	24128	24686	22496	20719
	Umin	10001	8294	5561	4155	2484	2313	1335	1299	1103	1093	884	1224	857
	Umax	23107	23156	21668	21673	21743	28749	20588	26697	25716	25391	24340	23712	21189

Table 19: Experiment's results for dataset Customer

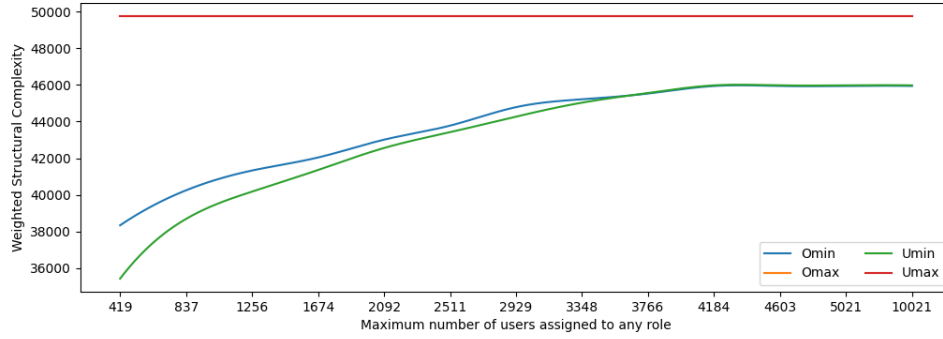


Figure 37: Dataset Customer: Weighted Structural Complexity

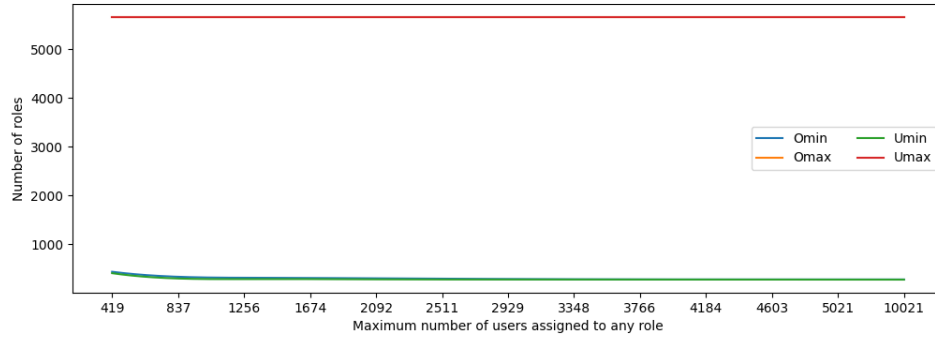


Figure 38: Dataset Customer: Number of roles

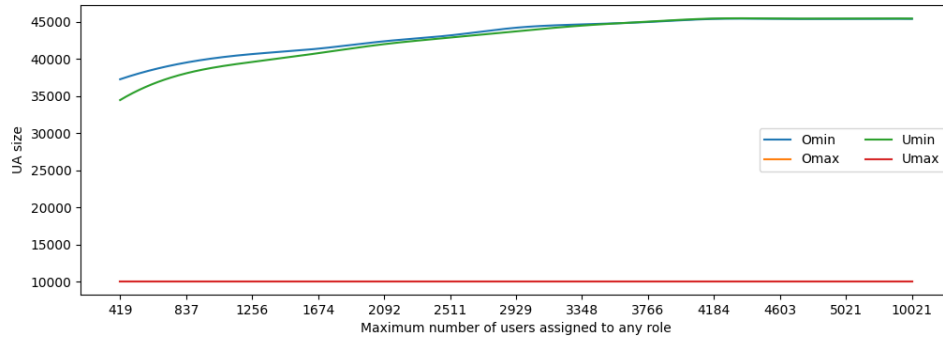


Figure 39: Dataset Customer: UA size

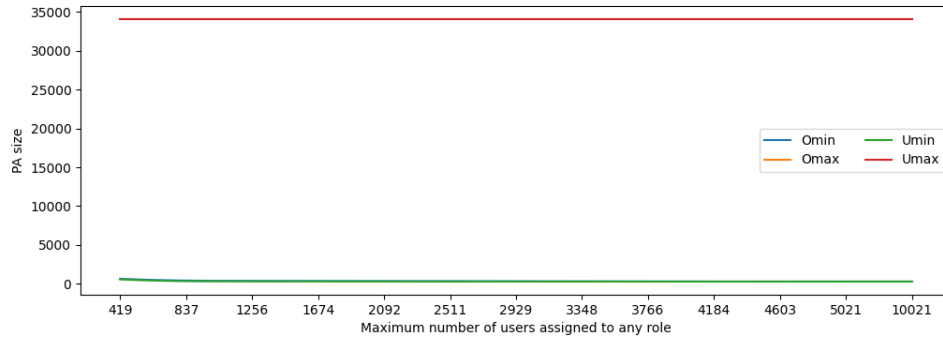


Figure 40: Dataset Customer: PA size

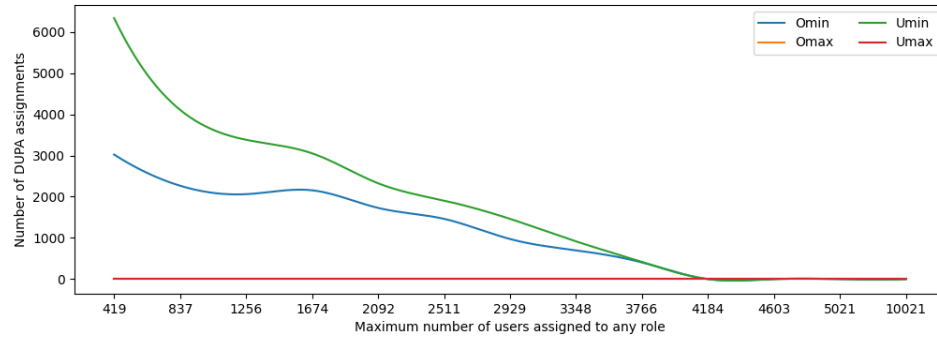


Figure 41: Dataset Customer: Number of DIPA assignments

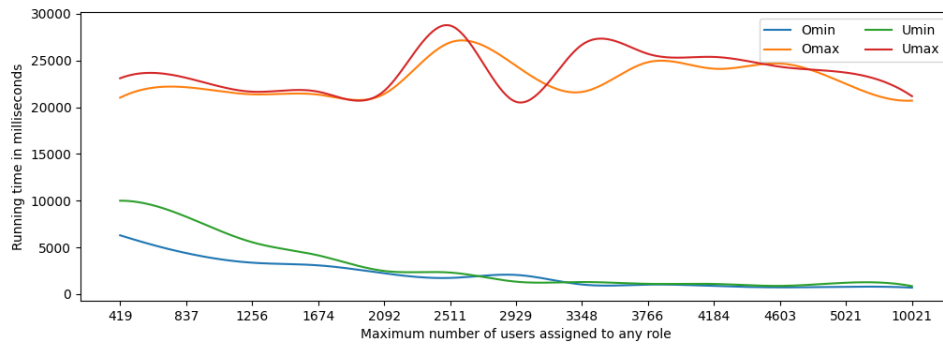


Figure 42: Dataset Customer: Running time in milliseconds

4.3 Duplicate Roles Forbidden - small μ value

M	V	1	2	3	4	5
WSC	Omin	48002	40548	36929	34836	33455
	Omax	48083	46759	46469	46295	46284
	Umin	48007	38277	33772	31204	29777
	Umax	48079	46973	46993	47078	47243
$ \mathcal{R} $	Omin	6163	5336	4713	4258	3901
	Omax	6170	5754	5612	5505	5446
	Umin	6164	5414	4836	4309	3899
	Umax	6167	5768	5671	5626	5612
$ \mathcal{UA} $	Omin	6163	9052	11141	12682	13978
	Omax	6170	6875	7252	7502	7707
	Umin	6164	9080	11441	13070	14238
	Umax	6167	6948	7380	7598	7782
$ \mathcal{PA} $	Omin	35676	26159	21075	17895	15575
	Omax	35742	34129	33605	33288	33130
	Umin	35678	23782	17495	13824	11638
	Umax	35744	34256	33940	33853	33848
$ \mathcal{DUPA} $	Omin	9750	9964	9859	9638	9432
	Omax	9684	7494	6601	6067	5663
	Umin	9748	10352	10739	11215	11442
	Umax	9682	7475	6336	5623	5125
time	Omin	36863	36101	28908	24694	25788
	Omax	33511	35330	31164	30628	30452
	Umin	27804	33020	26376	28443	30460
	Umax	37456	36539	26579	27148	26959

Table 20: Experiment's results for dataset Customer

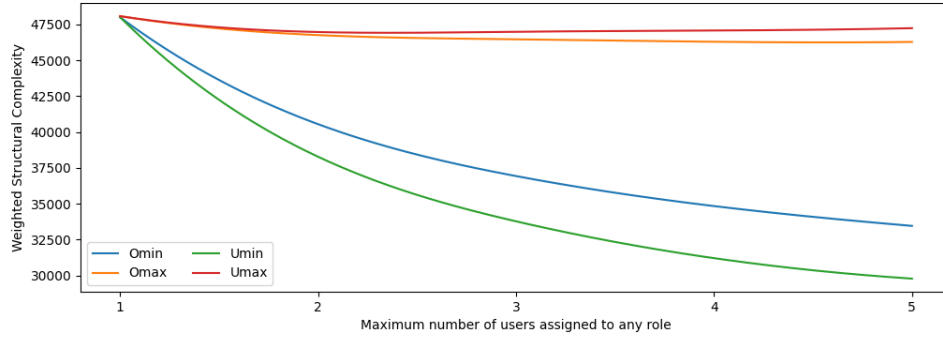


Figure 43: Dataset Customer: Weighted Structural Complexity

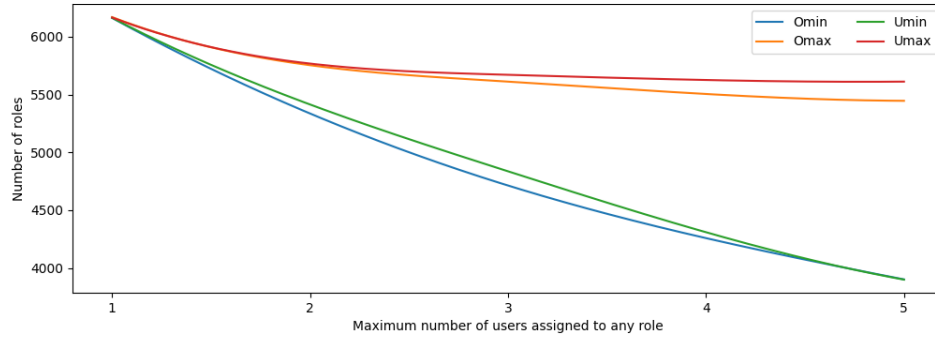


Figure 44: Dataset Customer: Number of roles

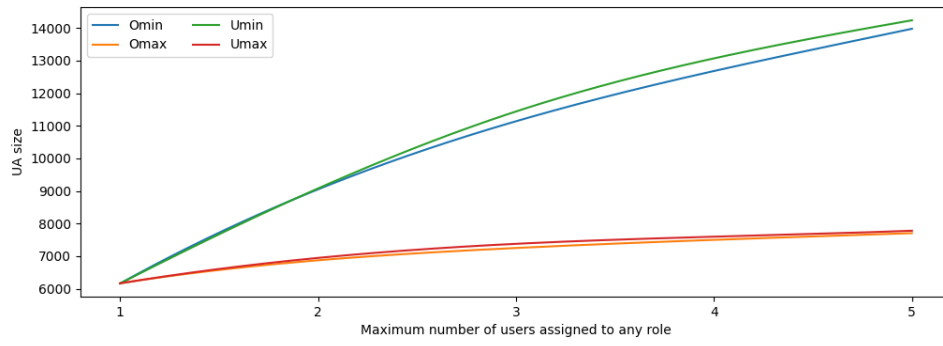


Figure 45: Dataset Customer: UA size

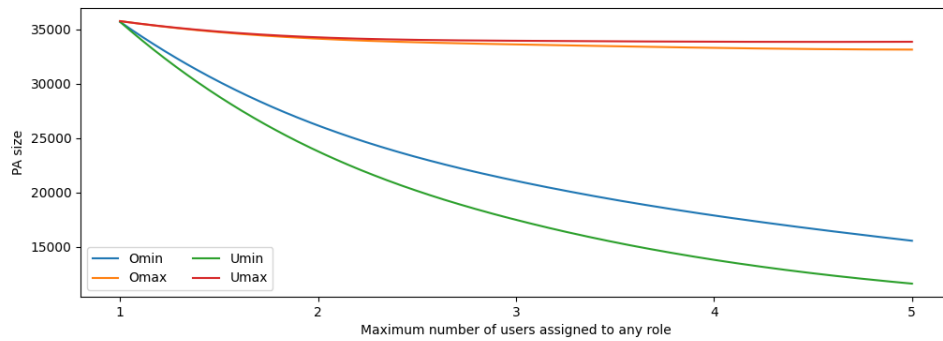


Figure 46: Dataset Customer: PA size

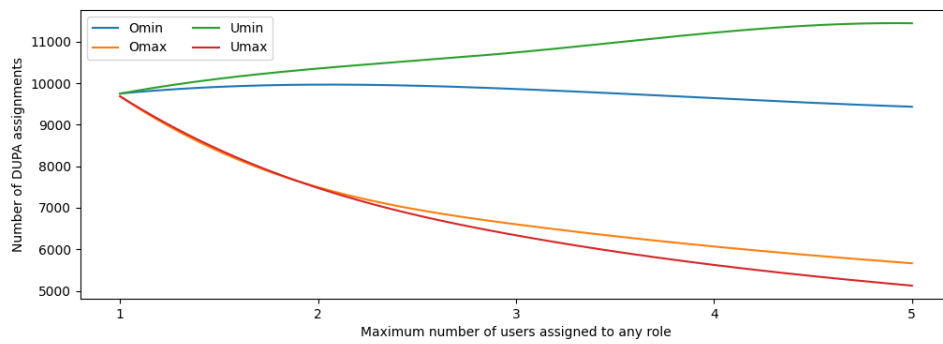


Figure 47: Dataset Customer: Number of DUPA assignments

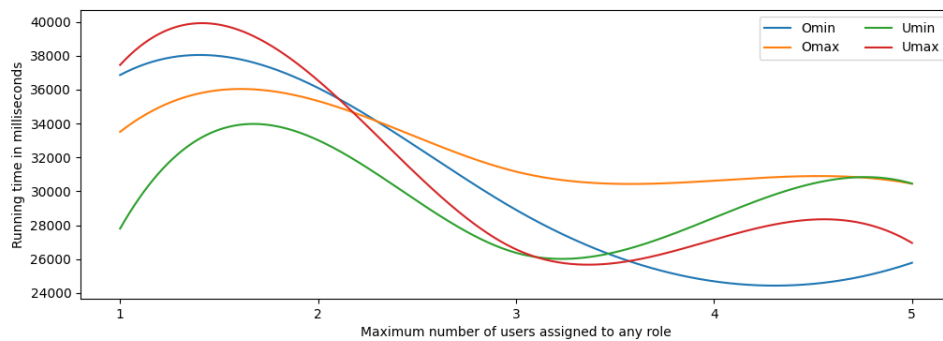


Figure 48: Dataset Customer: Running time in milliseconds

5 Dataset Domino

5.1 Allowing Duplicate Roles

μ	A ₁	A ₂	C ₁	C ₂	D ₁	D ₂	D ₃	D ₄	D ₅	D ₆	D ₇	D ₈	D ₉
6	40	31	56	60	37	31	40	36	33	29	38	31	40
11	29	24	47	35	27	25	29	29	25	26	35	25	29
16	25	22	26	25	24	22	25	24	22	24	33	22	25
21	23	22	24	24	22	22	23	24	22	24	33	22	23
26	21	21	22	22	21	21	21	23	21	24	33	21	21
31	21	21	21	21	21	21	21	23	21	23	32	21	21
36	21	21	21	21	21	21	21	23	21	23	32	21	21
41	21	21	21	21	21	21	21	23	21	23	32	21	21
46	21	20	21	21	21	20	21	22	20	23	32	20	21
51	21	20	21	21	20	20	21	22	20	23	32	20	21
57	20	20	20	20	20	20	20	22	20	23	32	20	20
62	20	20	20	20	20	20	20	22	20	23	32	20	20

Table 21: Role-set size for dataset Domino

μ	A ₁	A ₂	C ₁	C ₂	D ₁	D ₂	D ₃	D ₄	D ₅	D ₆	D ₇	D ₈	D ₉
6	802	770	1003	989	790	771	802	800	782	753	768	770	803
11	779	758	1078	873	768	757	779	784	764	746	761	755	780
16	771	758	852	803	762	751	771	774	758	741	756	749	772
21	767	758	825	794	758	751	767	774	758	741	756	749	768
26	763	756	808	779	756	749	763	772	756	741	756	747	764
31	763	756	798	770	756	749	763	772	756	739	754	747	764
36	763	756	798	770	756	749	763	772	756	739	754	747	764
41	763	756	798	770	756	749	763	772	756	739	754	747	764
46	763	754	799	770	756	747	763	770	754	739	754	745	764
51	763	754	799	770	754	747	763	770	754	739	754	745	764
57	761	754	789	761	754	747	761	770	754	739	754	745	762
62	761	754	789	761	754	747	761	770	754	739	754	745	762

Table 22: WSC values for dataset Domino

μ	A ₁	A ₂	C ₁	C ₂	D ₁	D ₂	D ₃	D ₄	D ₅	D ₆	D ₇	D ₈	D ₉
6	4	4	5	4	1	1	1	2	2	3	2	2	1
11	3	3	4	4	1	1	1	1	1	3	2	1	1
16	3	3	3	3	1	1	1	1	1	3	2	1	1
21	3	3	3	3	1	1	1	1	1	3	2	1	1
26	3	3	3	3	1	1	1	1	1	2	2	1	1
31	3	3	3	3	1	1	1	1	1	3	2	1	1
36	3	3	3	3	1	1	1	2	2	4	3	1	1
41	3	4	3	3	1	1	1	1	1	3	2	1	1
46	3	4	3	3	1	1	1	1	1	3	3	1	1
51	3	11	3	4	1	1	1	2	2	3	3	1	1
57	3	3	3	3	1	1	1	1	1	3	2	1	1
62	3	3	3	3	1	1	1	1	1	3	2	1	1

Table 23: Execution times for dataset Domino

5.2 Duplicate Roles Forbidden - large μ value

M	V	6	11	16	21	26	31	36	41	46	51	57	62	79
WSC	Omin	706	705	712	717	717	722	727	732	737	742	743	743	743
	Omax	712	721	726	731	736	739	739	739	739	739	739	739	739
	Umin	707	711	730	735	735	740	745	750	755	760	761	761	761
	Umax	712	721	726	731	736	739	739	739	739	739	739	739	739
$ \mathcal{R} $	Omin	25	22	21	21	20	20	20	20	20	20	20	20	20
	Omax	23	23	23	23	23	23	23	23	23	23	23	23	23
	Umin	26	22	21	21	20	20	20	20	20	20	20	20	20
	Umax	23	23	23	23	23	23	23	23	23	23	23	23	23
$ \mathcal{UA} $	Omin	98	109	120	125	128	133	138	143	148	153	154	154	154
	Omax	52	61	66	71	76	79	79	79	79	79	79	79	79
	Umin	100	112	142	148	151	156	161	166	171	176	177	177	177
	Umax	52	61	66	71	76	79	79	79	79	79	79	79	79
$ \mathcal{PA} $	Omin	583	574	571	571	569	569	569	569	569	569	569	569	569
	Omax	637	637	637	637	637	637	637	637	637	637	637	637	637
	Umin	581	577	567	566	564	564	564	564	564	564	564	564	564
	Umax	637	637	637	637	637	637	637	637	637	637	637	637	637
$ \mathcal{DUPA} $	Omin	49	33	28	28	26	21	16	11	6	1	0	0	0
	Omax	36	22	13	8	3	0	0	0	0	0	0	0	0
	Umin	50	36	28	28	26	21	16	11	6	1	0	0	0
	Umax	36	22	13	8	3	0	0	0	0	0	0	0	0
time	Omin	5	5	4	5	6	5	4	3	3	4	3	3	3
	Omax	4	6	4	5	4	5	4	3	3	3	3	3	3
	Umin	6	7	4	4	4	4	4	3	4	3	5	4	3
	Umax	4	5	4	4	4	4	3	3	4	3	4	5	3

Table 24: Experiment's results for dataset Domino

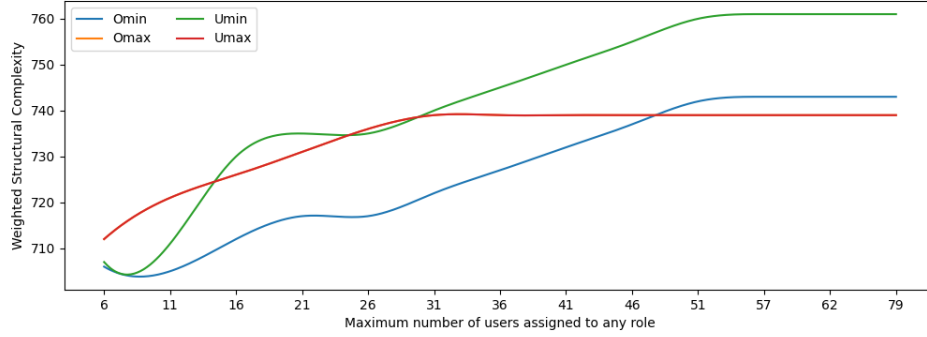


Figure 49: Dataset Domino: Weighted Structural Complexity

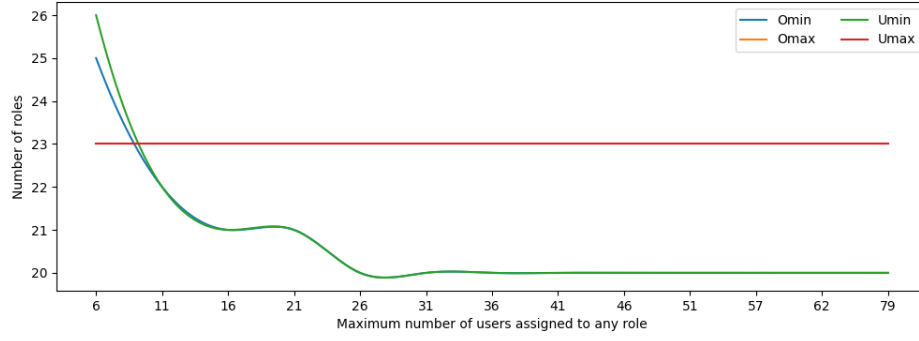


Figure 50: Dataset Domino: Number of roles

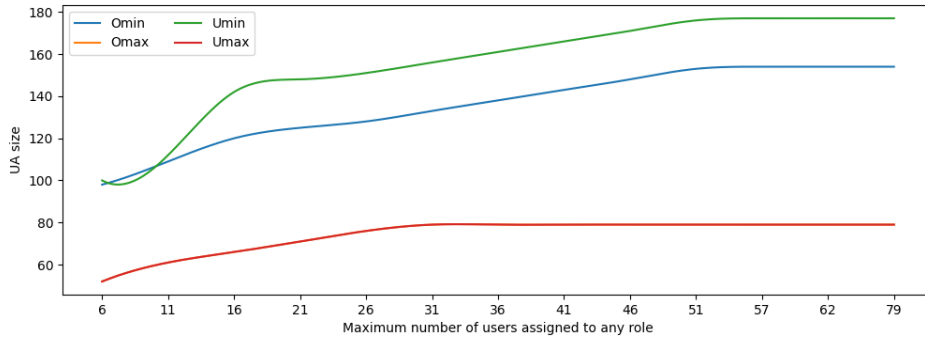


Figure 51: Dataset Domino: UA size

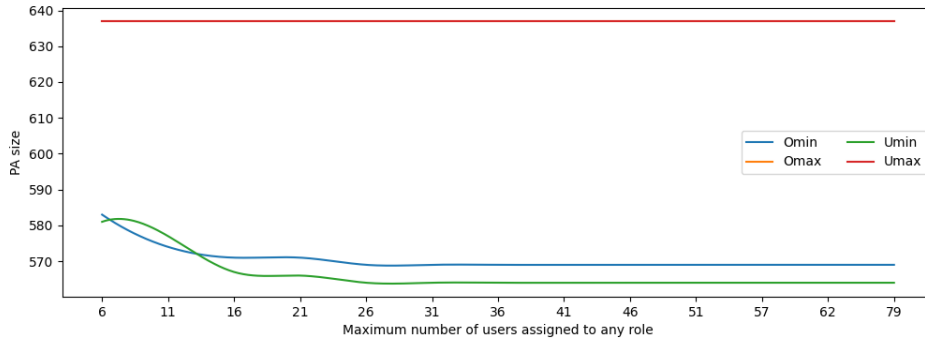


Figure 52: Dataset Domino: PA size

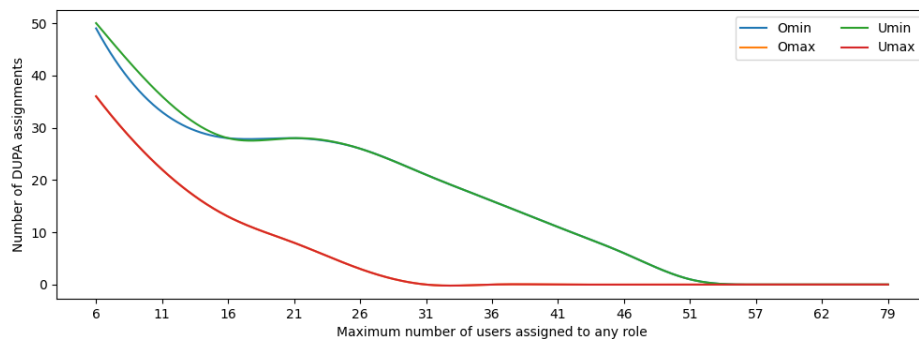


Figure 53: Dataset Domino: Number of DUPA assignments

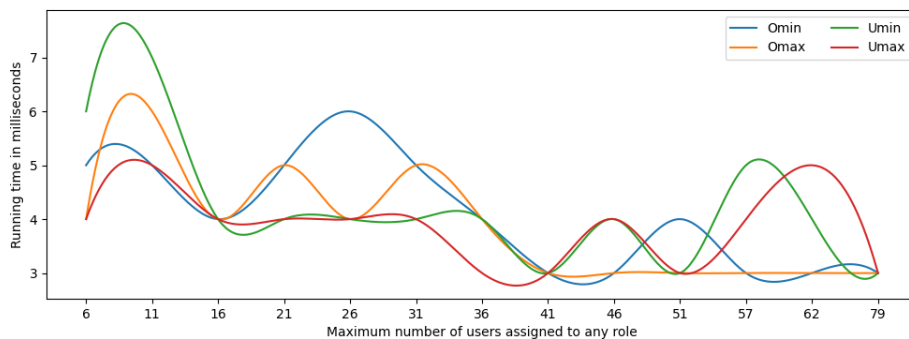


Figure 54: Dataset Domino: Running time in milliseconds

5.3 Duplicate Roles Forbidden - small μ value

M	V	1	2	3	4	5
WSC	Omin	710	708	713	707	707
	Omax	715	721	719	717	709
	Umin	710	709	713	704	703
	Umax	717	726	724	715	709
$ \mathcal{R} $	Omin	31	31	30	28	26
	Omax	31	30	27	27	23
	Umin	31	31	30	28	26
	Umax	32	31	28	26	23
$ \mathcal{UA} $	Omin	31	54	70	78	88
	Omax	31	43	49	49	49
	Umin	31	55	70	79	87
	Umax	32	46	52	49	49
$ \mathcal{PA} $	Omin	648	623	613	600	593
	Omax	651	647	641	641	637
	Umin	648	622	613	596	590
	Umax	652	649	644	640	637
$ \mathcal{DUPA} $	Omin	82	68	61	57	53
	Omax	78	58	51	44	40
	Umin	82	69	60	58	51
	Umax	77	56	49	44	40
time	Omin	5	5	5	5	5
	Omax	5	5	5	4	5
	Umin	5	5	5	8	4
	Umax	5	5	6	4	4

Table 25: Experiment's results for dataset Domino

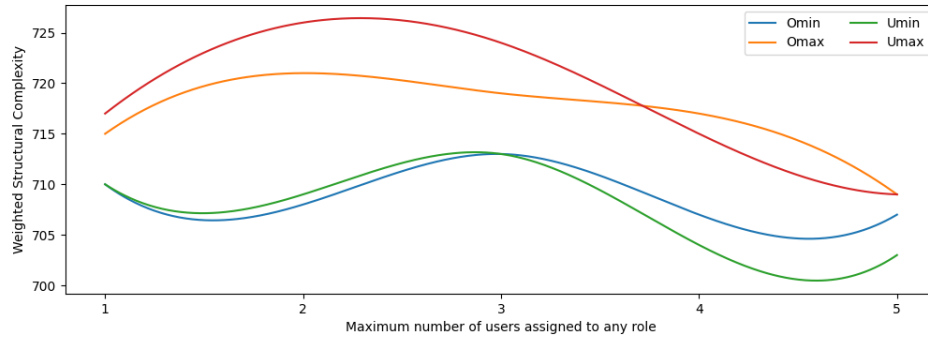


Figure 55: Dataset Domino: Weighted Structural Complexity

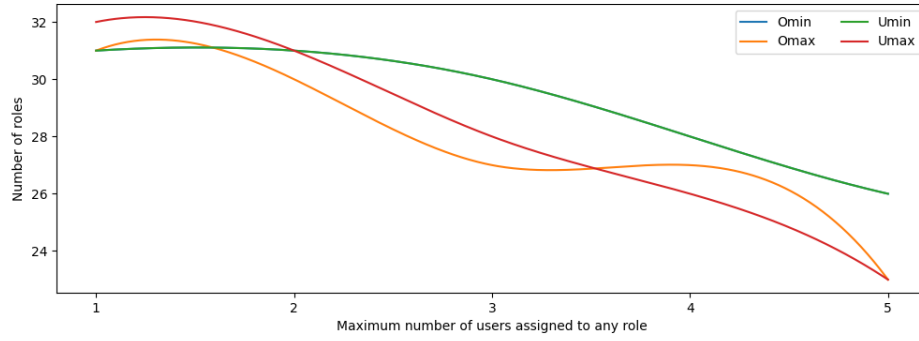


Figure 56: Dataset Domino: Number of roles

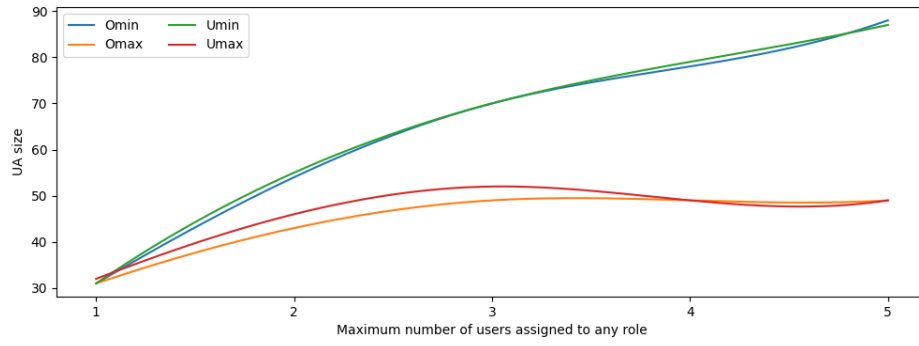


Figure 57: Dataset Domino: UA size

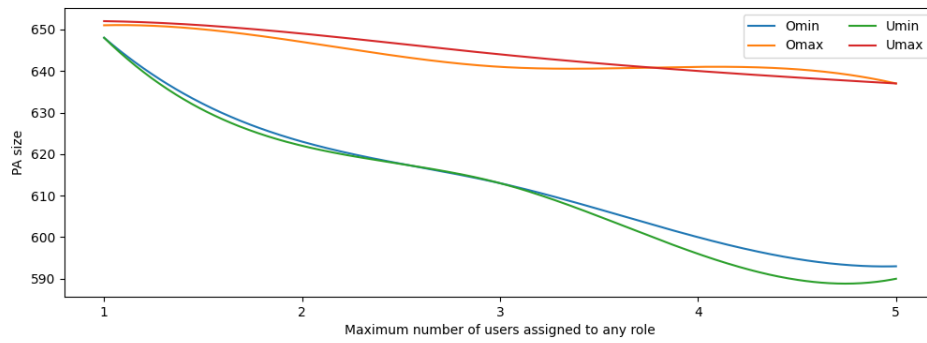


Figure 58: Dataset Domino: PA size

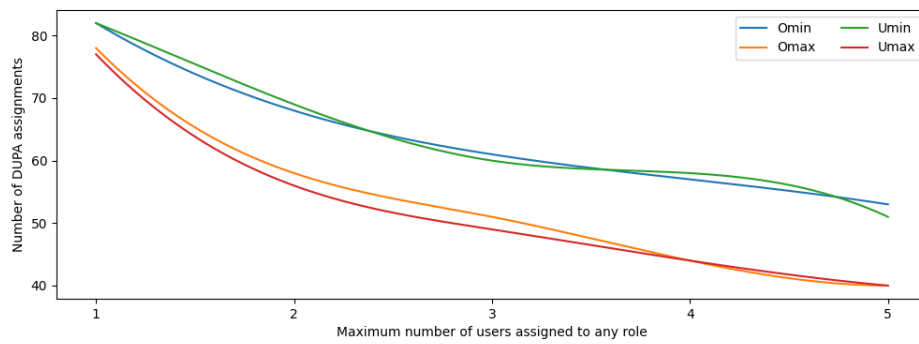


Figure 59: Dataset Domino: Number of DUPA assignments

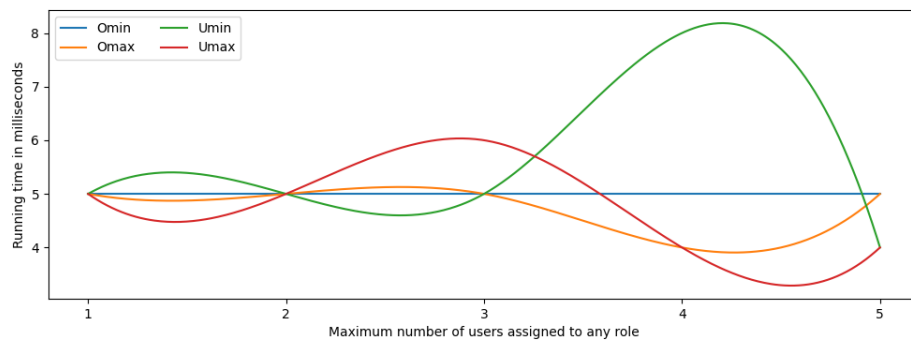


Figure 60: Dataset Domino: Running time in milliseconds

6 Dataset Emea

6.1 Allowing Duplicate Roles

μ	A ₁	A ₂	C ₁	C ₂	D ₁	D ₂	D ₃	D ₄	D ₅	D ₆	D ₇	D ₈	D ₉
1	35	35	35	35	35	35	35	41	35	35	267	35	35
2	34	34	34	34	34	34	34	40	34	34	158	34	34
3	34	34	34	34	34	34	34	40	34	34	157	34	34
4	34	34	34	34	34	34	34	40	34	34	157	34	34

Table 26: Role-set size for dataset Emea

μ	A ₁	A ₂	C ₁	C ₂	D ₁	D ₂	D ₃	D ₄	D ₅	D ₆	D ₇	D ₈	D ₉
1	7290	7290	7290	7290	7290	7290	7290	7605	7290	7290	21629	7290	7290
2	7280	7280	7280	7280	7280	7280	7280	7595	7280	7280	12495	7280	7280
3	7280	7280	7280	7280	7280	7280	7280	7595	7280	7280	12486	7280	7280
4	7280	7280	7280	7280	7280	7280	7280	7595	7280	7280	12486	7280	7280

Table 27: *WSC* values for dataset Emea

μ	A ₁	A ₂	C ₁	C ₂	D ₁	D ₂	D ₃	D ₄	D ₅	D ₆	D ₇	D ₈	D ₉
1	43	47	38	32	9	9	8	8	8	23	23	9	7
2	31	41	43	35	7	7	7	7	7	24	22	9	9
3	39	44	31	31	7	7	7	7	7	22	22	9	8
4	35	42	44	32	7	7	7	7	7	25	23	12	8

Table 28: Execution times for dataset Emea

6.2 Duplicate Roles Forbidden - large μ value

M	V	1	2	3	4	35
WSC	Omin	7292	7280	7280	7280	7280
	Omax	7292	7280	7280	7280	7280
	Umin	7292	7280	7280	7280	7280
	Umax	7292	7280	7280	7280	7280
$ \mathcal{R} $	Omin	36	34	34	34	34
	Omax	36	34	34	34	34
	Umin	36	34	34	34	34
	Umax	36	34	34	34	34
$ \mathcal{UA} $	Omin	36	35	35	35	35
	Omax	36	35	35	35	35
	Umin	36	35	35	35	35
	Umax	36	35	35	35	35
$ \mathcal{PA} $	Omin	7220	7211	7211	7211	7211
	Omax	7220	7211	7211	7211	7211
	Umin	7220	7211	7211	7211	7211
	Umax	7220	7211	7211	7211	7211
$ \mathcal{DUPA} $	Omin	0	0	0	0	0
	Omax	0	0	0	0	0
	Umin	0	0	0	0	0
	Umax	0	0	0	0	0
time	Omin	43	37	33	37	37
	Omax	38	37	41	40	37
	Umin	33	41	37	34	37
	Umax	37	36	33	37	37

Table 29: Experiment's results for dataset Emea

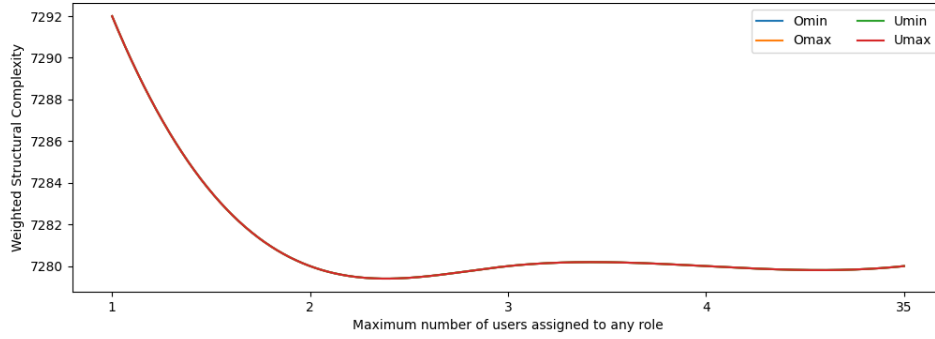


Figure 61: Dataset Emea: Weighted Structural Complexity

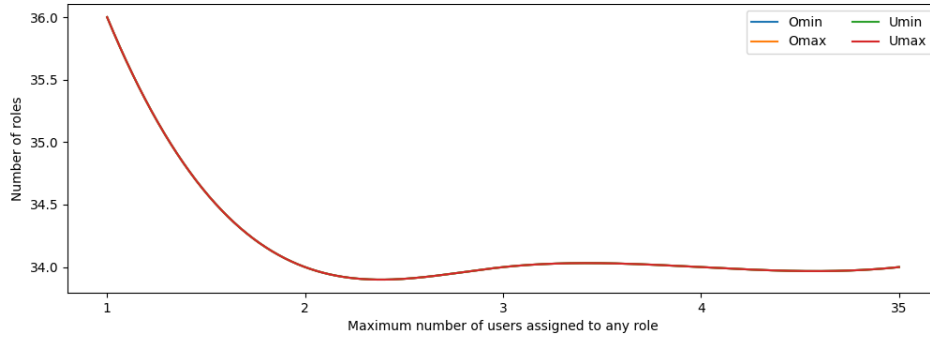


Figure 62: Dataset Emea: Number of roles

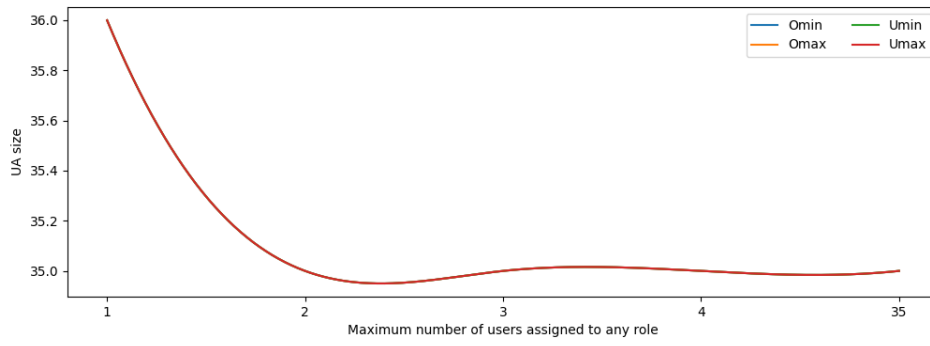


Figure 63: Dataset Emea: UA size

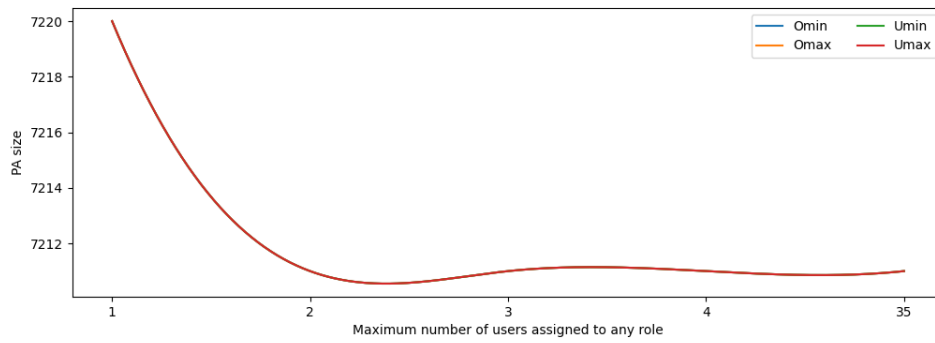


Figure 64: Dataset Emea: PA size

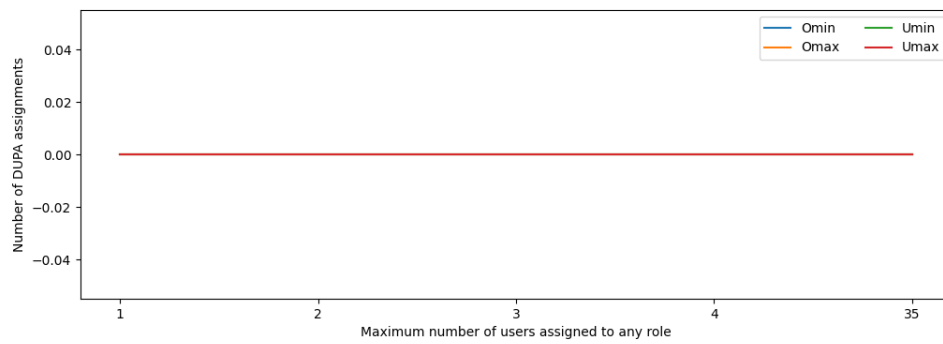


Figure 65: Dataset Emea: Number of DUPA assignments

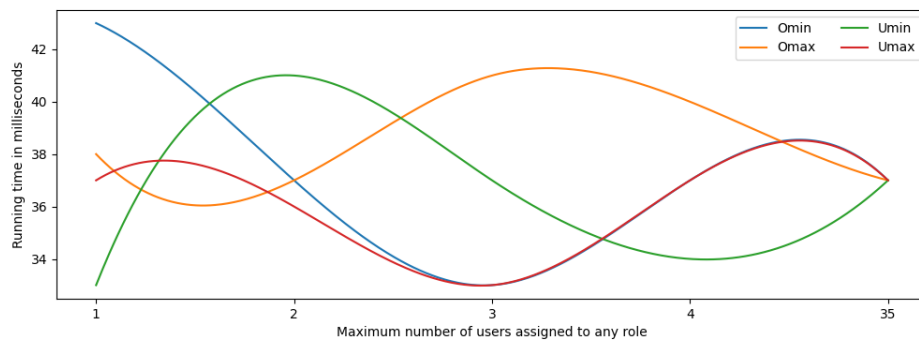


Figure 66: Dataset Emea: Running time in milliseconds

6.3 Duplicate Roles Forbidden - small μ value

M	V	1	2	3	4	5
WSC	Omin	7292	7280	7280	7280	7280
	Omax	7292	7280	7280	7280	7280
	Umin	7292	7280	7280	7280	7280
	Umax	7292	7280	7280	7280	7280
$ \mathcal{R} $	Omin	36	34	34	34	34
	Omax	36	34	34	34	34
	Umin	36	34	34	34	34
	Umax	36	34	34	34	34
$ \mathcal{UA} $	Omin	36	35	35	35	35
	Omax	36	35	35	35	35
	Umin	36	35	35	35	35
	Umax	36	35	35	35	35
$ \mathcal{PA} $	Omin	7220	7211	7211	7211	7211
	Omax	7220	7211	7211	7211	7211
	Umin	7220	7211	7211	7211	7211
	Umax	7220	7211	7211	7211	7211
$ \mathcal{DUPA} $	Omin	0	0	0	0	0
	Omax	0	0	0	0	0
	Umin	0	0	0	0	0
	Umax	0	0	0	0	0
time	Omin	38	38	34	38	34
	Omax	37	34	39	34	37
	Umin	33	41	37	37	37
	Umax	37	38	34	37	34

Table 30: Experiment's results for dataset Emea

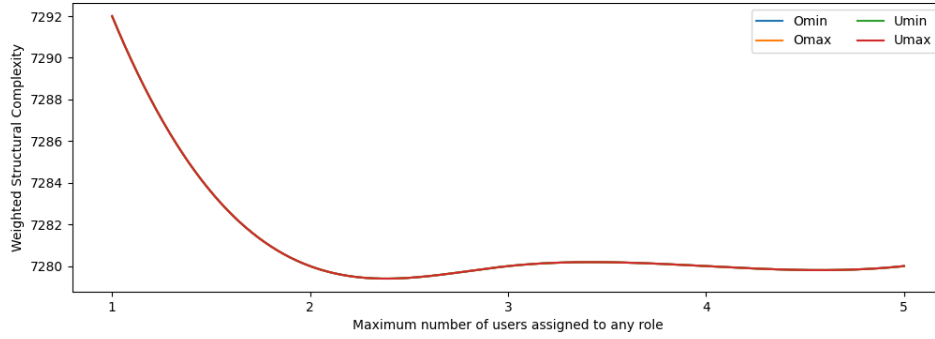


Figure 67: Dataset Emea: Weighted Structural Complexity

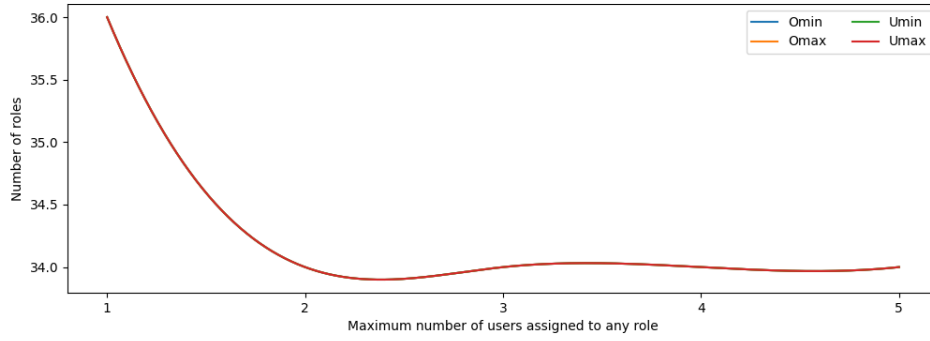


Figure 68: Dataset Emea: Number of roles

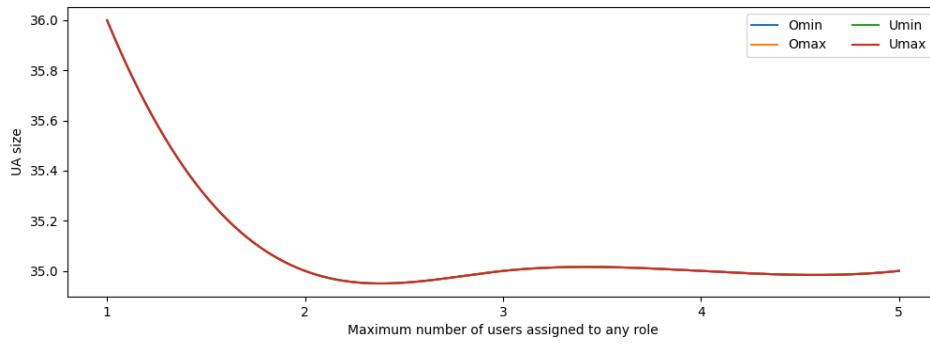


Figure 69: Dataset Emea: UA size

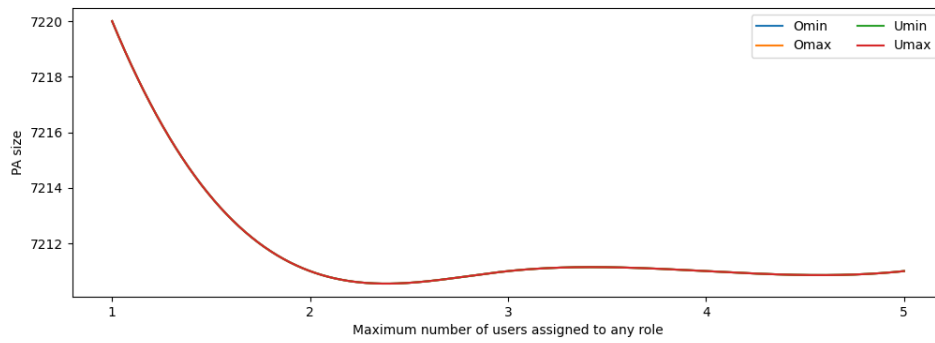


Figure 70: Dataset Emea: PA size

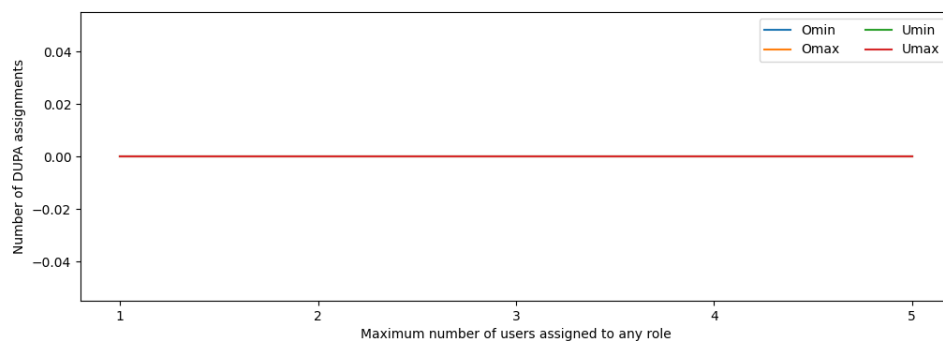


Figure 71: Dataset Emea: Number of DIPA assignments

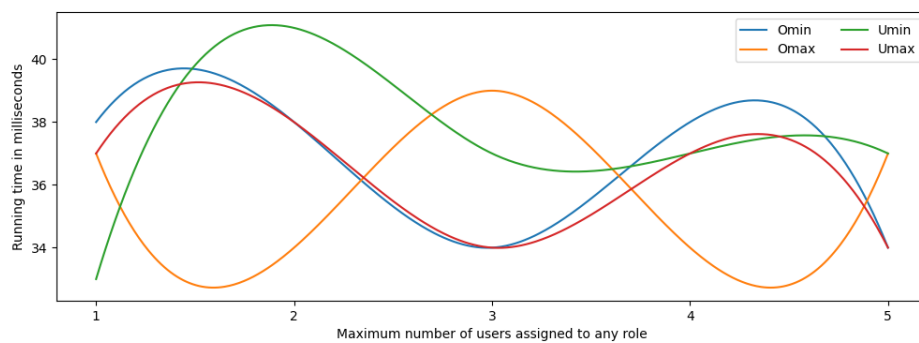


Figure 72: Dataset Emea: Running time in milliseconds

7 Dataset Firewall 1

7.1 Allowing Duplicate Roles

μ	A ₁	A ₂	C ₁	C ₂	D ₁	D ₂	D ₃	D ₄	D ₅	D ₆	D ₇	D ₈	D ₉
21	148	81	161	152	94	84	153	109	96	96	125	80	136
41	104	73	98	112	78	77	102	89	79	93	121	71	97
61	91	71	94	96	73	75	90	83	73	92	120	69	87
82	85	70	92	90	71	73	83	80	71	91	119	67	81
102	81	70	91	87	69	73	80	79	69	91	119	67	79
122	77	70	84	85	69	73	76	78	69	91	119	67	76
143	76	70	84	84	69	71	75	78	68	90	118	67	76
163	76	67	84	84	68	71	75	76	67	90	118	65	74
183	76	67	83	84	67	71	75	75	65	90	118	65	73
203	75	67	82	82	66	71	74	75	65	90	118	65	72
224	71	67	72	74	66	71	70	74	65	90	118	65	70
244	70	67	72	69	66	71	69	74	65	90	118	65	69

Table 31: Role-set size for dataset Firewall 1

μ	A ₁	A ₂	C ₁	C ₂	D ₁	D ₂	D ₃	D ₄	D ₅	D ₆	D ₇	D ₈	D ₉
21	4570	5664	15717	6212	3256	5893	4580	4975	5510	7904	9063	4855	6543
41	3887	5009	8467	4589	2531	5390	3821	4334	4852	7520	8569	4247	5873
61	3702	5004	8488	4249	2346	5277	3609	4198	4706	7410	8459	4136	5742
82	3559	4978	8734	4333	2240	5164	3493	4090	4598	7300	8349	4025	5632
102	3486	4996	9094	4495	2131	5164	3406	4084	4579	7300	8349	4025	5617
122	3457	5012	7994	4670	2131	5164	3377	4068	4579	7300	8349	4025	5597
143	3390	5027	8344	4826	2131	5051	3310	4068	4573	7190	8239	4025	5597
163	3390	4822	8684	5064	2128	5051	3310	3976	4471	7190	8239	3914	5516
183	3390	4822	8859	5302	2122	5051	3310	3970	4452	7190	8239	3914	5510
203	3384	4822	9023	5540	2019	5051	3304	3970	4452	7190	8239	3914	5501
224	3344	4822	6765	4052	2019	5051	3264	3954	4452	7190	8239	3914	5484
244	3322	4822	6816	3370	2019	5051	3261	3954	4452	7190	8239	3914	5481

Table 32: WSC values for dataset Firewall 1

μ	A ₁	A ₂	C ₁	C ₂	D ₁	D ₂	D ₃	D ₄	D ₅	D ₆	D ₇	D ₈	D ₉
21	99	81	116	91	12	16	12	18	16	88	83	18	14
41	78	79	90	95	11	15	11	16	16	84	81	15	11
61	82	83	104	86	9	13	10	17	15	84	81	14	11
82	75	88	104	87	8	14	10	17	15	86	82	14	11
102	79	77	93	88	8	13	12	17	16	85	86	15	11
122	73	93	87	87	9	13	10	17	15	89	81	16	11
143	74	79	85	89	11	15	11	16	16	84	81	14	11
163	73	76	86	91	9	14	10	17	15	86	81	14	11
183	87	76	93	85	8	13	11	16	15	85	82	14	10
203	74	80	84	90	9	13	10	17	15	85	81	16	12
224	75	78	80	89	8	13	10	16	16	86	85	15	20
244	76	100	87	82	9	13	10	16	18	86	81	15	11

Table 33: Execution times for dataset Firewall 1

7.2 Duplicate Roles Forbidden - large μ value

M	V	21	41	61	82	102	122	143	163	183	203	224	244	365
WSC	Omin	4923	4211	3944	3829	3744	3632	3523	3483	3442	3422	3334	3297	3223
	Omax	8171	7622	7484	7341	7331	7301	7190	7190	7190	7190	7190	7190	7190
	Umin	4808	4195	3965	3986	3946	3871	3698	3598	3498	3399	3311	3267	3193
	Umax	8151	7614	7473	7339	7306	7258	7190	7190	7190	7190	7190	7190	7190
$ \mathcal{R} $	Omin	131	102	94	86	84	79	77	77	76	74	70	67	65
	Omax	112	97	95	92	92	92	90	90	90	90	90	90	90
	Umin	159	111	100	92	87	82	80	80	80	76	72	70	68
	Umax	104	96	94	92	92	92	90	90	90	90	90	90	90
$ \mathcal{U}\mathcal{A} $	Omin	1991	2406	2523	2524	2526	2455	2414	2374	2334	2334	2291	2262	2256
	Omax	680	496	460	410	399	370	365	365	365	365	365	365	365
	Umin	2391	2533	2562	2712	2773	2770	2665	2565	2465	2375	2332	2292	2286
	Umax	516	463	433	410	394	378	365	365	365	365	365	365	365
$ \mathcal{P}\mathcal{A} $	Omin	2800	1701	1327	1218	1134	1098	1032	1032	1031	1014	973	968	902
	Omax	7379	7029	6928	6838	6840	6838	6735	6735	6735	6735	6735	6735	6735
	Umin	2257	1550	1303	1182	1085	1019	953	953	953	948	907	905	839
	Umax	7530	7055	6945	6837	6820	6788	6735	6735	6735	6735	6735	6735	6735
$ \mathcal{DUP}\mathcal{A} $	Omin	16	0	0	0	0	0	0	0	0	0	0	0	0
	Omax	12	0	0	0	0	0	0	0	0	0	0	0	0
	Umin	36	102	172	92	70	0	0	0	0	0	0	0	0
	Umax	0	0	0	0	0	0	0	0	0	0	0	0	0
time	Omin	97	90	85	85	82	119	100	86	97	134	89	98	97
	Omax	92	83	83	81	88	95	113	138	91	96	93	89	84
	Umin	105	95	96	86	134	95	112	97	126	97	85	86	82
	Umax	88	89	86	90	126	107	97	88	174	86	104	88	89

Table 34: Experiment's results for dataset Firewall 1

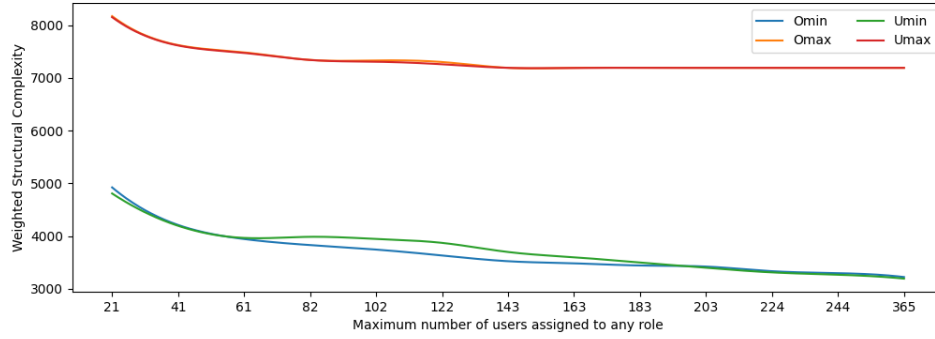


Figure 73: Dataset Firewall 1: Weighted Structural Complexity

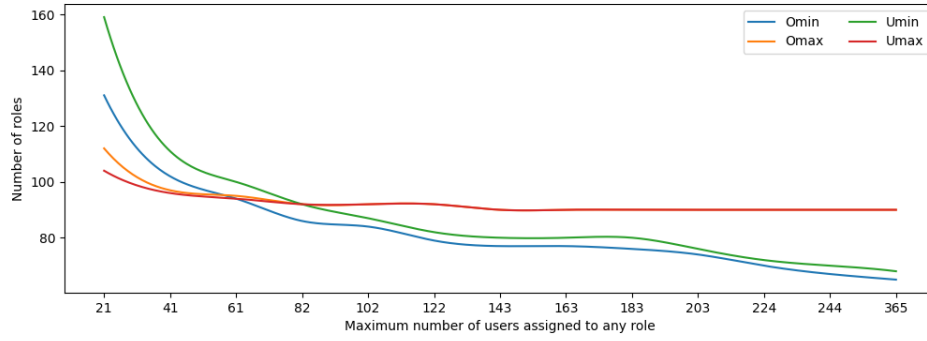


Figure 74: Dataset Firewall 1: Number of roles

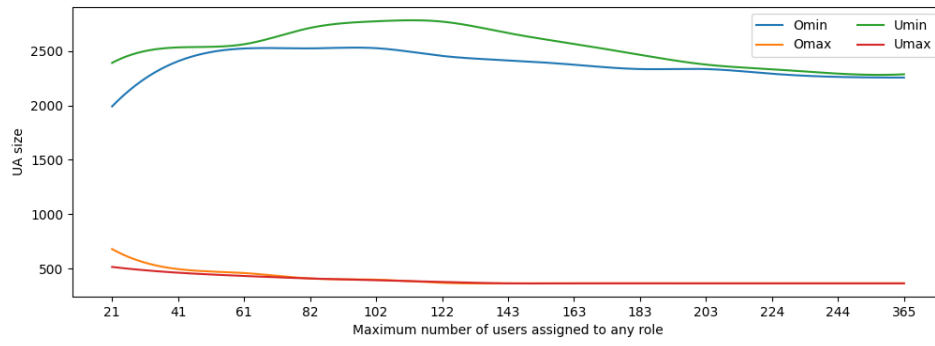


Figure 75: Dataset Firewall 1: UA size

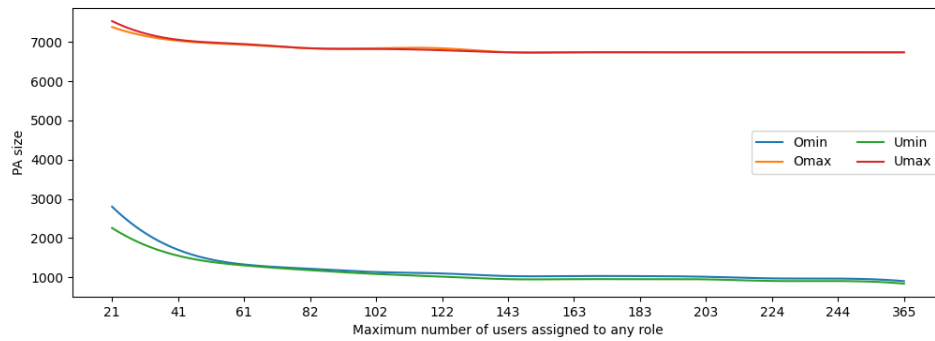


Figure 76: Dataset Firewall 1: PA size

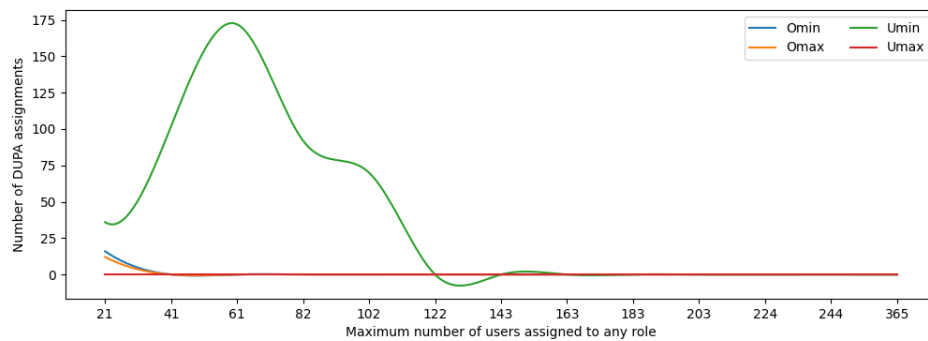


Figure 77: Dataset Firewall 1: Number of DUPA assignments

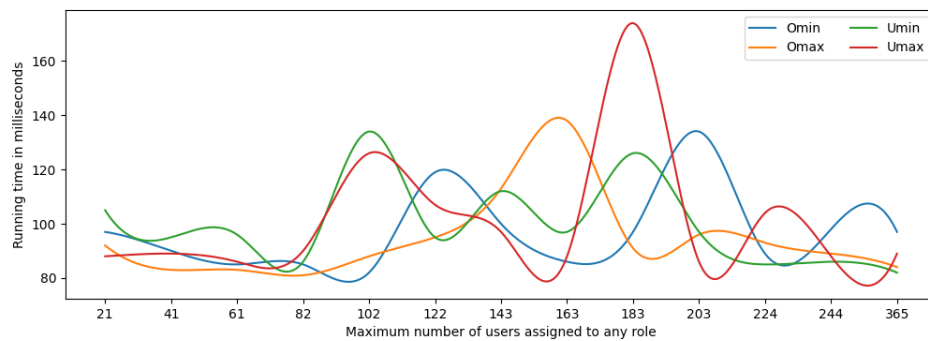


Figure 78: Dataset Firewall 1: Running time in milliseconds

7.3 Duplicate Roles Forbidden - small μ value

M	V	1	2	3	4	5
WSC	Omin	33155	18286	13057	10637	9432
	Omax	33148	19721	15433	13323	12067
	Umin	33157	17907	13113	10388	8880
	Umax	33151	20839	16172	13905	12451
$ \mathcal{R} $	Omin	615	444	343	299	280
	Omax	613	394	326	287	258
	Umin	615	460	421	352	320
	Umax	614	360	257	213	187
$ \mathcal{UA} $	Omin	615	879	994	1143	1294
	Omax	613	716	841	907	962
	Umin	615	905	1209	1334	1487
	Umax	614	649	643	628	631
$ \mathcal{PA} $	Omin	31925	16963	11719	9194	7858
	Omax	31921	18611	14265	12128	10847
	Umin	31926	16541	11483	8702	7072
	Umax	31923	19830	15271	13062	11633
$ \mathcal{DUPA} $	Omin	25	40	34	31	28
	Omax	29	19	20	15	16
	Umin	24	44	93	67	31
	Umax	28	15	10	6	2
time	Omin	281	192	163	137	129
	Omax	226	151	139	120	113
	Umin	291	206	154	145	140
	Umax	227	160	132	120	109

Table 35: Experiment's results for dataset Firewall 1

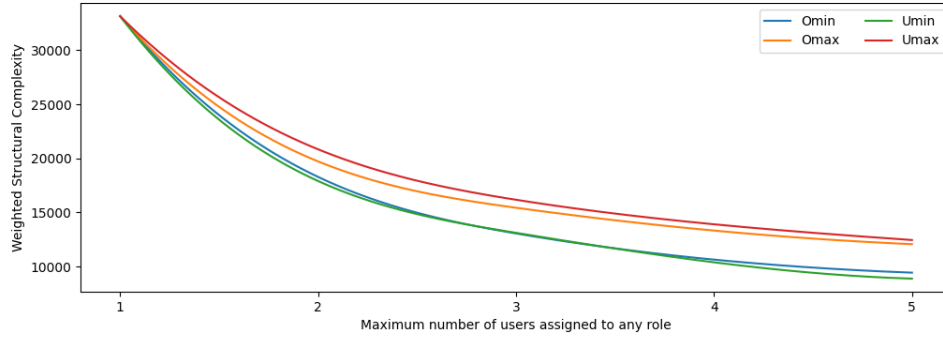


Figure 79: Dataset Firewall 1: Weighted Structural Complexity

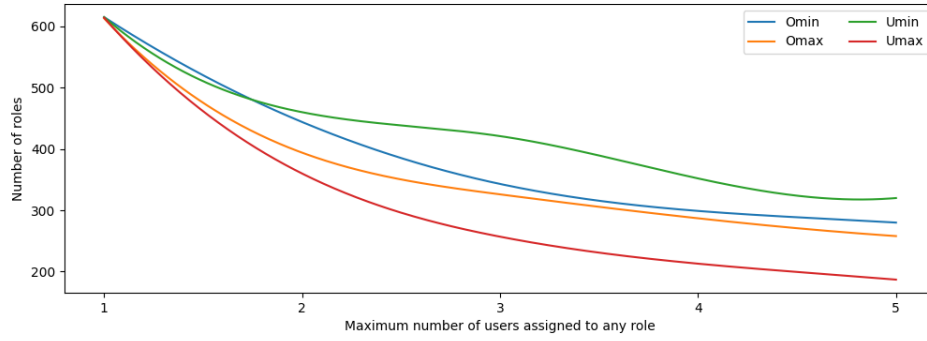


Figure 80: Dataset Firewall 1: Number of roles

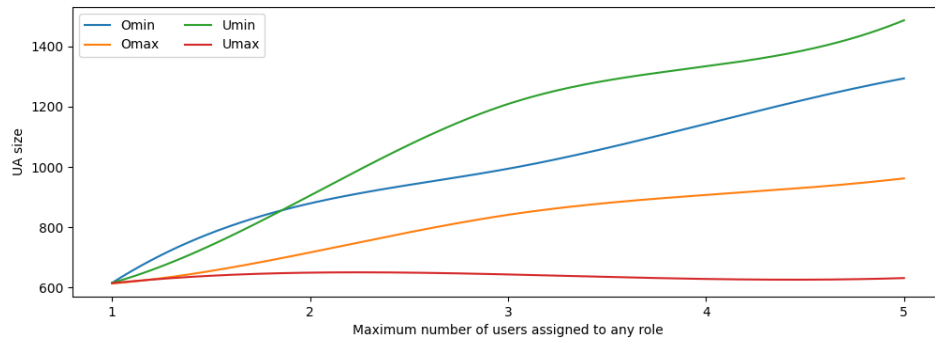


Figure 81: Dataset Firewall 1: UA size

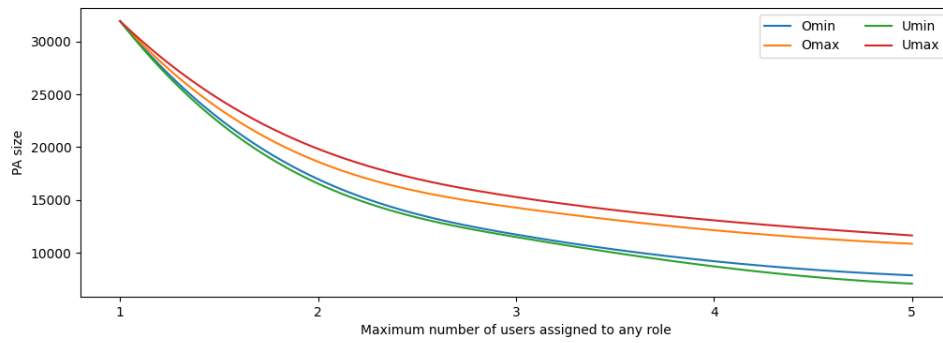


Figure 82: Dataset Firewall 1: PA size

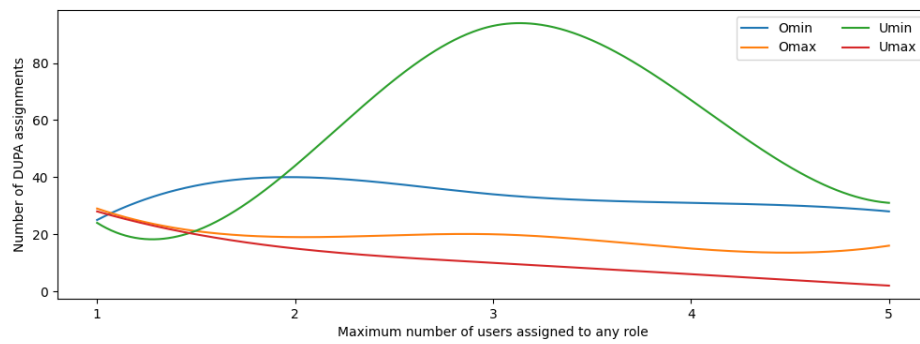


Figure 83: Dataset Firewall 1: Number of DUPA assignments

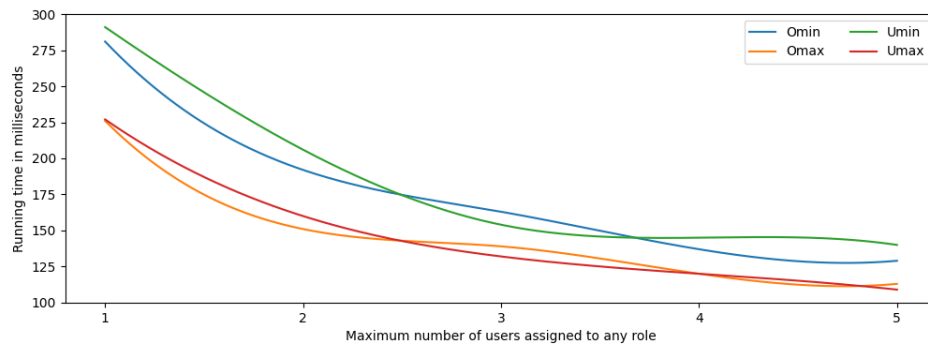


Figure 84: Dataset Firewall 1: Running time in milliseconds

8 Dataset Firewall 2

8.1 Allowing Duplicate Roles

μ	A ₁	A ₂	C ₁	C ₂	D ₁	D ₂	D ₃	D ₄	D ₅	D ₆	D ₇	D ₈	D ₉
24	40	21	46	53	24	21	45	22	21	21	26	21	41
48	22	14	37	42	15	14	25	14	14	15	17	14	22
72	18	13	17	22	13	13	18	13	13	14	14	13	18
96	14	12	13	15	12	12	14	12	12	13	13	12	13
120	12	11	12	12	11	11	12	11	11	12	12	11	12
144	11	11	11	11	11	11	11	11	11	12	12	11	11
168	11	11	11	11	11	11	11	11	11	12	12	11	11
192	11	11	11	11	11	11	11	11	11	12	12	11	11
216	11	11	11	11	11	11	11	11	11	12	12	11	11
239	11	10	11	11	10	10	11	10	10	11	11	10	11
263	11	10	11	11	10	10	11	10	10	11	11	10	11
287	10	10	10	10	10	10	10	10	10	11	11	10	10

Table 36: Role-set size for dataset Firewall 2

μ	A ₁	A ₂	C ₁	C ₂	D ₁	D ₂	D ₃	D ₄	D ₅	D ₆	D ₇	D ₈	D ₉
24	2616	2268	3483	3370	2198	2258	2721	2177	2258	2263	2454	2270	2643
48	1885	1538	3399	3189	1476	1538	1987	1456	1538	1582	1718	1550	1911
72	1884	1520	2362	2198	1174	1520	1661	1438	1520	1564	1375	1532	1869
96	1837	1502	2096	1797	1156	1502	1614	1420	1502	1546	1357	1514	1811
120	1823	1484	2052	1649	1138	1484	1600	1402	1484	1528	1339	1496	1808
144	1805	1484	1986	1584	1138	1484	1582	1402	1484	1528	1339	1496	1790
168	1805	1484	1988	1585	1138	1484	1582	1402	1484	1528	1339	1496	1790
192	1805	1484	1997	1594	1138	1484	1582	1402	1484	1528	1339	1496	1790
216	1805	1484	2010	1607	1138	1484	1582	1402	1484	1528	1339	1496	1790
239	1805	1466	2033	1630	1120	1466	1582	1384	1466	1510	1321	1478	1790
263	1805	1466	2046	1643	1120	1466	1582	1384	1466	1510	1321	1478	1790
287	1787	1466	1965	1564	1120	1466	1564	1384	1466	1510	1321	1478	1772

Table 37: WSC values for dataset Firewall 2

μ	A ₁	A ₂	C ₁	C ₂	D ₁	D ₂	D ₃	D ₄	D ₅	D ₆	D ₇	D ₈	D ₉
24	82	75	90	93	17	11	8	20	19	13	13	10	7
48	77	73	86	94	17	11	7	18	19	13	12	10	7
72	77	74	81	88	22	12	9	22	19	13	12	10	7
96	75	74	80	84	14	9	7	18	19	13	12	10	7
120	78	75	82	84	14	10	7	18	18	13	12	10	7
144	77	76	81	83	13	10	7	18	18	13	12	10	7
168	75	76	97	87	13	9	7	18	18	13	12	10	7
192	75	73	87	83	14	10	7	19	18	13	12	10	7
216	75	73	80	86	14	10	7	18	19	13	12	10	7
239	76	73	79	86	14	10	8	19	18	13	12	10	7
263	75	89	82	85	13	10	7	18	19	14	13	10	7
287	76	74	78	86	13	10	7	18	18	13	12	10	6

Table 38: Execution times for dataset Firewall 2

8.2 Duplicate Roles Forbidden - large μ value

M	V	24	48	72	96	120	144	168	192	216	239	263	287	325
WSC	Omin	2865	2140	1883	1729	1697	1654	1630	1606	1582	1559	1535	1494	1494
	Omax	2493	1760	1717	1674	1631	1607	1583	1559	1535	1510	1510	1510	1510
	Umin	2832	2131	1982	1813	1767	1724	1700	1676	1652	1629	1605	1564	1564
	Umax	2493	1760	1717	1674	1631	1607	1583	1559	1535	1510	1510	1510	1510
$ \mathcal{R} $	Omin	47	27	24	16	14	12	12	12	12	12	12	10	10
	Omax	31	19	17	15	13	13	13	13	13	11	11	11	11
	Umin	47	27	26	18	14	12	12	12	12	12	12	10	10
	Umax	31	19	17	15	13	13	13	13	13	11	11	11	11
$ \mathcal{UA} $	Omin	1051	1082	1151	1058	1030	1006	982	958	934	911	887	865	865
	Omax	545	499	475	451	427	403	379	355	331	325	325	325	325
	Umin	1069	1105	1276	1158	1128	1104	1080	1056	1032	1009	985	963	963
	Umax	545	499	475	451	427	403	379	355	331	325	325	325	325
$ \mathcal{PA} $	Omin	1767	1031	708	655	653	636	636	636	636	636	636	619	619
	Omax	1917	1242	1225	1208	1191	1191	1191	1191	1191	1174	1174	1174	1174
	Umin	1716	999	680	637	625	608	608	608	608	608	608	591	591
	Umax	1917	1242	1225	1208	1191	1191	1191	1191	1191	1174	1174	1174	1174
$ \mathcal{DUPA} $	Omin	8	0	0	0	0	0	0	0	0	0	0	0	0
	Omax	0	0	0	0	0	0	0	0	0	0	0	0	0
	Umin	10	2	0	0	0	0	0	0	0	0	0	0	0
	Umax	0	0	0	0	0	0	0	0	0	0	0	0	0
time	Omin	90	117	95	81	82	81	87	81	81	81	93	108	93
	Omax	81	94	80	77	77	77	77	79	76	78	108	104	91
	Umin	87	98	101	83	79	84	79	79	77	116	98	83	88
	Umax	104	96	80	90	94	88	89	87	88	89	86	87	94

Table 39: Experiment's results for dataset Firewall 2

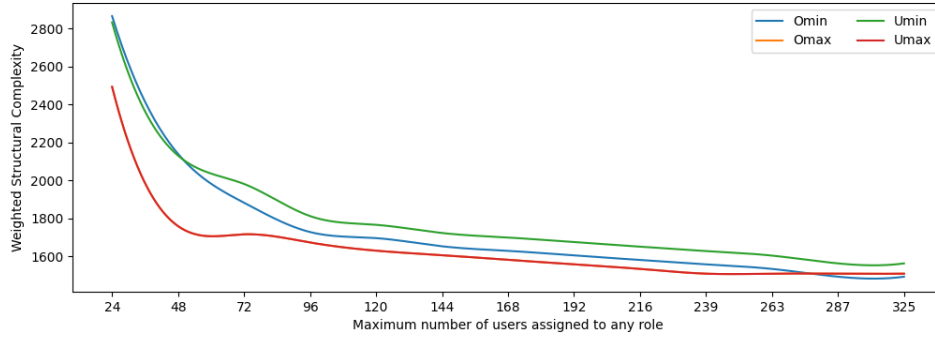


Figure 85: Dataset Firewall 2: Weighted Structural Complexity

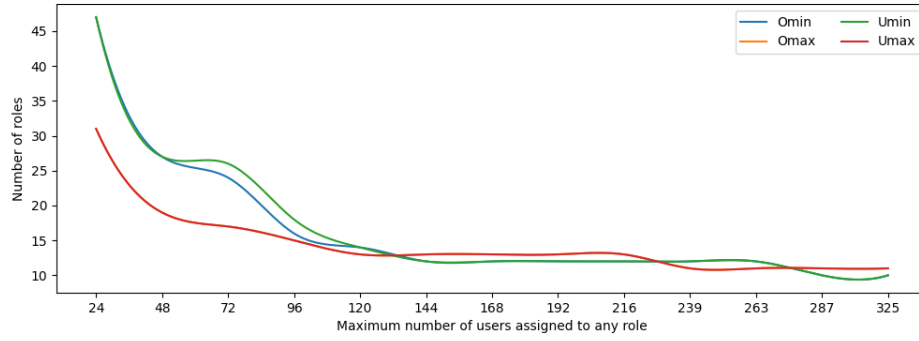


Figure 86: Dataset Firewall 2: Number of roles

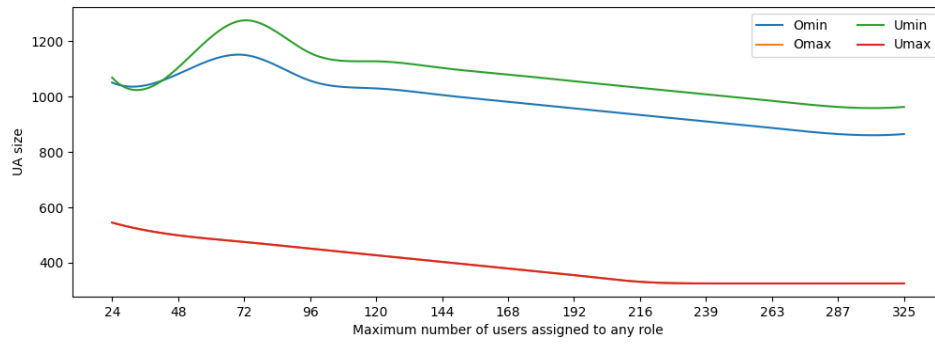


Figure 87: Dataset Firewall 2: UA size

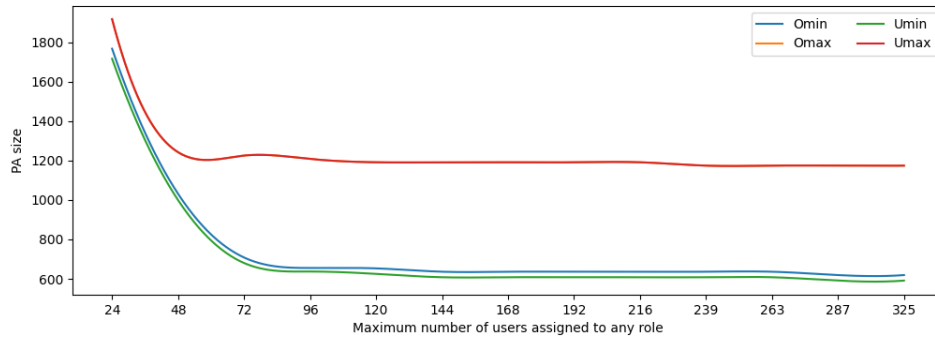


Figure 88: Dataset Firewall 2: PA size

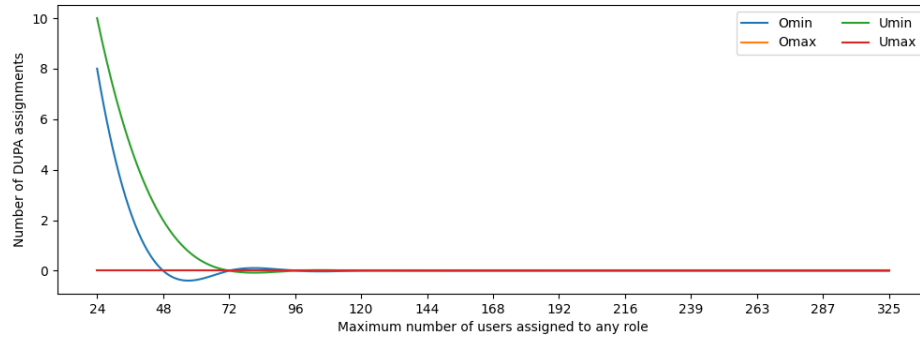


Figure 89: Dataset Firewall 2: Number of DUPA assignments

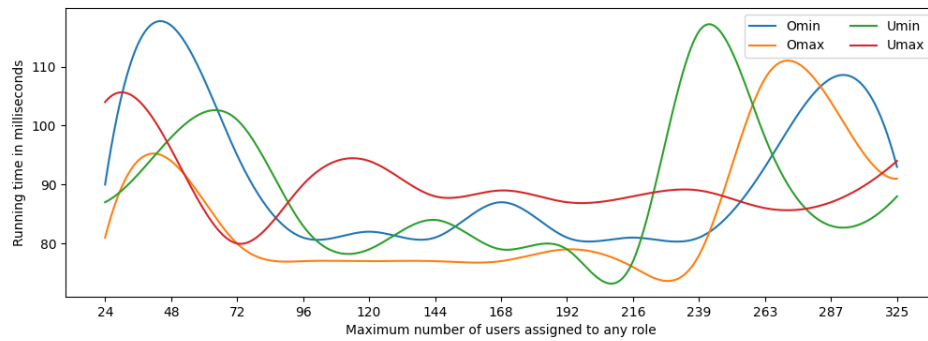


Figure 90: Dataset Firewall 2: Running time in milliseconds

8.3 Duplicate Roles Forbidden - small μ value

M	V	1	2	3	4	5
WSC	Omin	37706	19796	13904	10814	8872
	Omax	37706	19390	13675	10555	8828
	Umin	37706	19864	13963	10620	9060
	Umax	37706	19418	13680	10533	8811
$ \mathcal{R} $	Omin	639	427	314	251	200
	Omax	639	327	217	168	137
	Umin	639	453	328	257	209
	Umax	639	321	215	163	133
$ \mathcal{UA} $	Omin	639	852	936	990	982
	Omax	639	646	631	638	640
	Umin	639	904	976	1014	1019
	Umax	639	634	628	620	617
$ \mathcal{PA} $	Omin	36428	18516	12654	9573	7689
	Omax	36428	18416	12827	9749	8050
	Umin	36428	18505	12657	9347	7832
	Umax	36428	18462	12836	9750	8061
$ \mathcal{DUPA} $	Omin	0	0	2	2	13
	Omax	0	1	2	0	0
	Umin	0	0	0	10	13
	Umax	0	0	0	0	0
time	Omin	293	176	143	124	120
	Omax	241	157	131	112	101
	Umin	282	172	150	132	139
	Umax	257	147	123	119	103

Table 40: Experiment's results for dataset Firewall 2

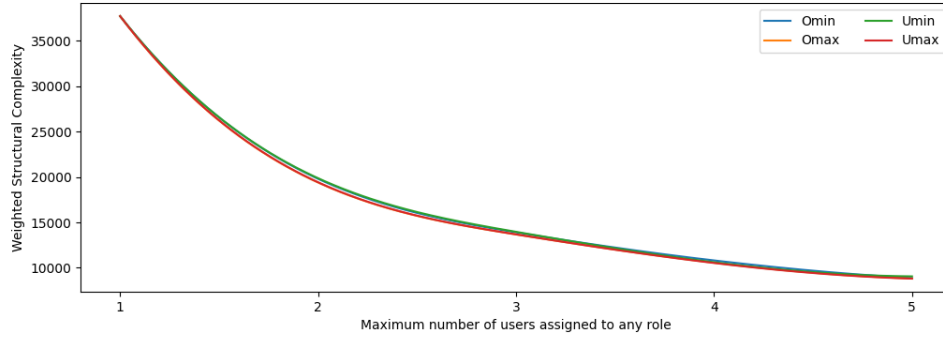


Figure 91: Dataset Firewall 2: Weighted Structural Complexity

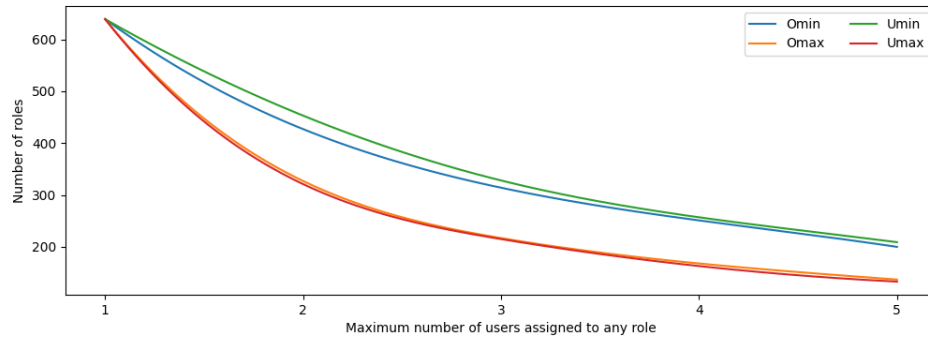


Figure 92: Dataset Firewall 2: Number of roles

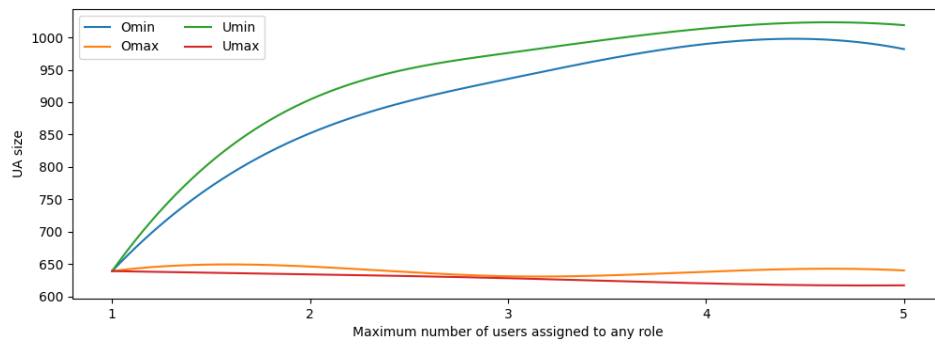


Figure 93: Dataset Firewall 2: UA size

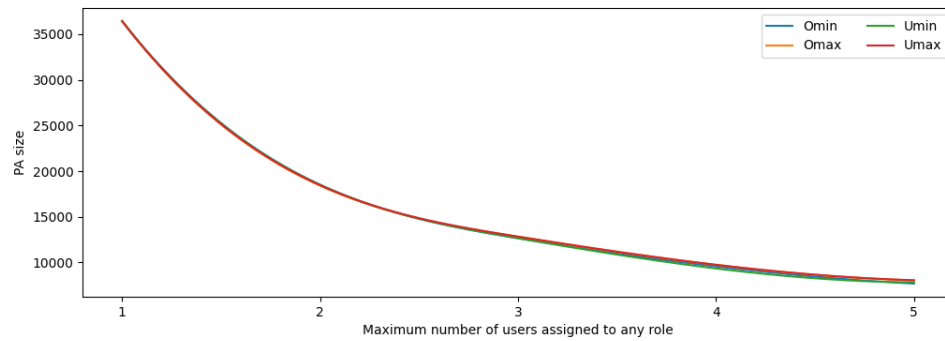


Figure 94: Dataset Firewall 2: PA size

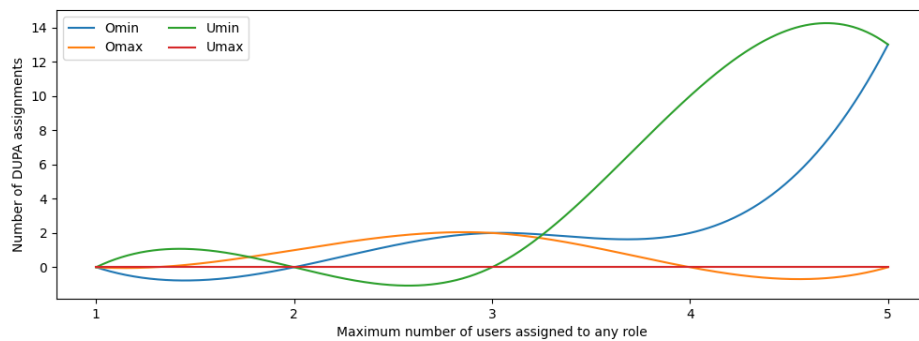


Figure 95: Dataset Firewall 2: Number of DUPA assignments

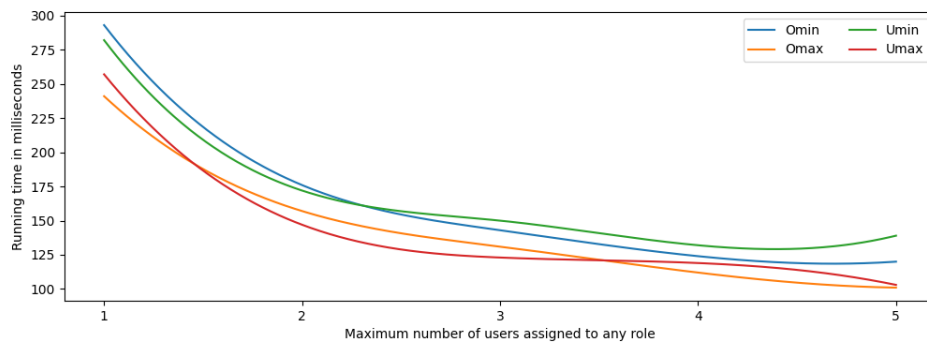


Figure 96: Dataset Firewall 2: Running time in milliseconds

9 Dataset Healthcare

9.1 Allowing Duplicate Roles

μ	A ₁	A ₂	C ₁	C ₂	D ₁	D ₂	D ₃	D ₄	D ₅	D ₆	D ₇	D ₈	D ₉
3	41	25	35	44	48	22	98	25	47	23	23	25	47
6	28	18	29	38	29	18	52	17	26	20	19	17	27
9	22	15	28	28	23	17	39	15	21	19	18	15	21
11	22	15	28	30	21	17	31	15	19	19	18	15	20
14	22	15	24	25	19	17	28	15	19	19	18	15	20
17	17	14	21	22	17	16	25	14	17	18	17	14	17
19	16	14	21	22	17	16	23	14	15	18	17	14	15
22	16	14	18	21	16	16	19	14	14	18	17	14	15
25	16	14	18	19	15	16	17	14	14	18	17	14	15
27	17	14	18	17	14	16	17	14	14	18	17	14	15
30	18	14	18	15	14	16	15	14	14	18	17	14	15
33	15	14	18	15	14	16	15	14	14	18	17	14	15

Table 41: Role-set size for dataset Healthcare

μ	A ₁	A ₂	C ₁	C ₂	D ₁	D ₂	D ₃	D ₄	D ₅	D ₆	D ₇	D ₈	D ₉
3	681	830	1128	849	717	746	915	754	1135	769	770	754	757
6	442	601	976	656	471	586	619	520	690	655	610	520	533
9	347	382	1005	460	397	540	514	471	574	609	564	471	480
11	347	384	1055	492	341	540	487	471	519	609	564	471	458
14	328	387	970	412	335	540	459	471	519	609	564	471	458
17	287	344	905	399	303	494	431	425	485	563	518	425	421
19	285	344	940	406	303	494	420	425	436	563	518	425	408
22	281	344	845	396	270	494	404	425	403	563	518	425	408
25	254	344	863	363	267	494	379	425	403	563	518	425	408
27	274	344	873	363	264	494	379	425	403	563	518	425	408
30	267	344	886	380	264	494	374	425	403	563	518	425	408
33	311	344	895	378	264	494	374	425	403	563	518	425	408

Table 42: WSC values for dataset Healthcare

μ	A ₁	A ₂	C ₁	C ₂	D ₁	D ₂	D ₃	D ₄	D ₅	D ₆	D ₇	D ₈	D ₉
3	4	4	4	4	2	4	3	2	2	5	6	3	1
6	3	3	4	4	1	2	1	1	2	4	4	2	1
9	3	3	4	3	1	2	1	1	2	4	4	2	1
11	3	3	4	3	1	2	1	1	2	4	4	2	1
14	3	3	4	3	1	2	1	1	1	4	4	2	1
17	4	3	5	4	1	2	1	1	2	5	4	2	1
19	4	4	4	4	2	3	2	1	2	4	4	2	1
22	3	3	3	3	1	2	1	1	1	4	4	2	1
25	3	3	3	3	1	2	1	1	1	4	4	2	1
27	3	3	3	3	1	2	1	1	1	4	4	2	1
30	3	3	3	3	1	2	1	2	3	5	4	2	1
33	4	4	4	4	1	2	1	2	2	4	4	2	1

Table 43: Execution times for dataset Healthcare

9.2 Duplicate Roles Forbidden - large μ value

M	V	3	6	9	11	14	17	19	22	25	27	30	33	46
WSC	Omin	962	679	530	533	509	468	451	442	412	409	406	403	368
	Omax	790	669	615	611	609	563	563	563	563	563	563	563	563
	Umin	776	549	474	473	392	396	388	379	349	346	373	370	352
	Umax	821	667	602	614	610	563	563	563	563	563	563	563	563
$ \mathcal{R} $	Omin	55	38	35	34	31	27	24	22	18	17	16	16	14
	Omax	29	23	20	20	20	18	18	18	18	18	18	18	18
	Umin	55	41	34	32	26	25	24	23	19	17	16	16	14
	Umax	30	22	19	20	20	18	18	18	18	18	18	18	18
$ \mathcal{UA} $	Omin	163	219	298	313	329	317	315	315	312	311	311	308	296
	Omax	63	64	53	51	50	46	46	46	46	46	46	46	46
	Umin	157	214	248	262	215	252	247	241	238	235	273	270	279
	Umax	66	56	53	51	47	46	46	46	46	46	46	46	46
$ \mathcal{PA} $	Omin	743	422	197	186	149	124	112	105	82	81	79	79	58
	Omax	697	581	541	539	539	499	499	499	499	499	499	499	499
	Umin	564	294	192	179	151	119	117	115	92	94	84	84	59
	Umax	724	588	529	542	543	499	499	499	499	499	499	499	499
$ \mathcal{DUPA} $	Omin	0	6	1	1	1	1	1	6	4	2	0	0	0
	Omax	3	2	0	0	1	0	0	0	0	0	0	0	0
	Umin	1	4	2	5	5	2	2	3	3	2	0	0	0
	Umax	0	0	0	0	0	0	0	0	0	0	0	0	0
time	Omin	9	5	4	4	4	4	4	5	4	4	4	5	4
	Omax	6	4	4	3	5	4	4	5	4	4	4	4	4
	Umin	8	6	4	4	5	6	4	4	4	4	5	4	4
	Umax	5	5	4	4	4	4	4	4	4	4	5	4	4

Table 44: Experiment's results for dataset Healthcare

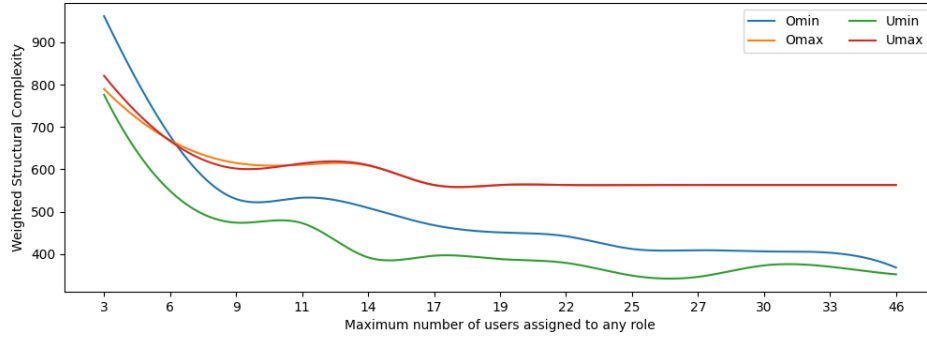


Figure 97: Dataset Healthcare: Weighted Structural Complexity

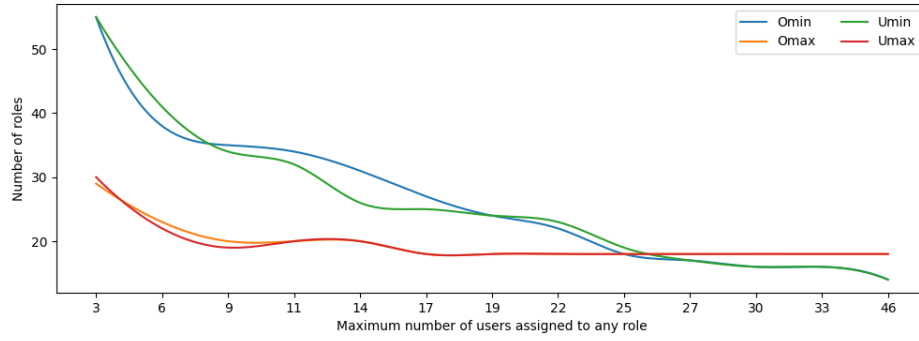


Figure 98: Dataset Healthcare: Number of roles

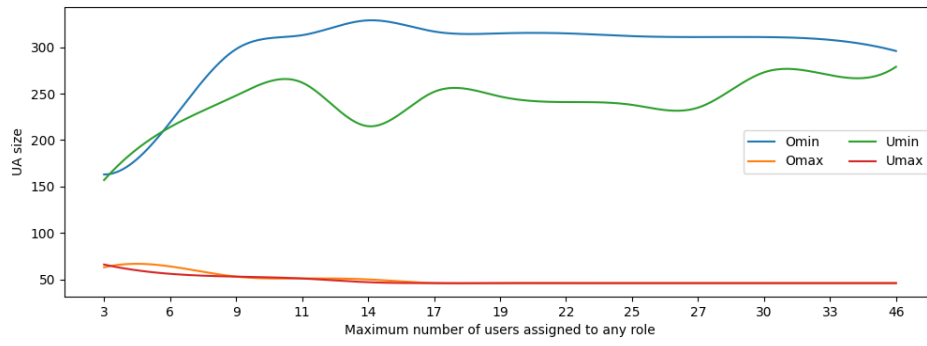


Figure 99: Dataset Healthcare: UA size

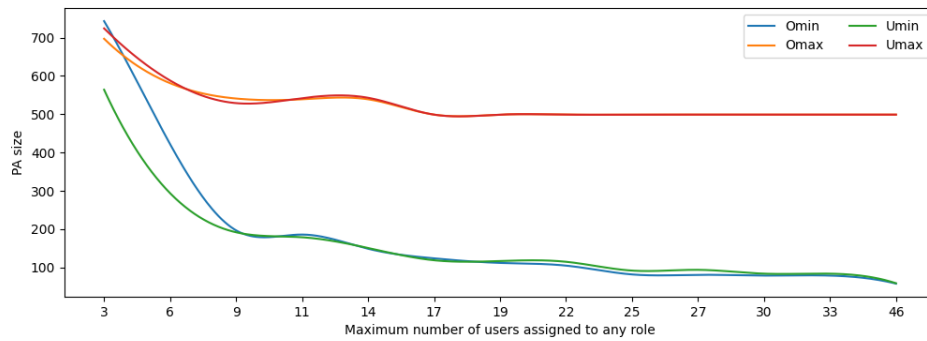


Figure 100: Dataset Healthcare: PA size

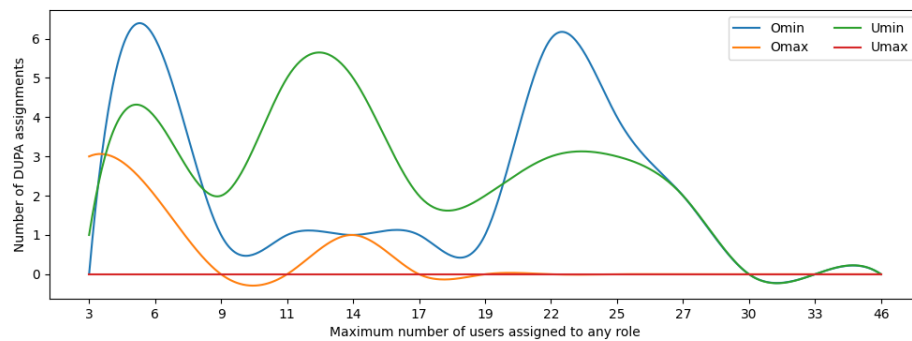


Figure 101: Dataset Healthcare: Number of DIPA assignments

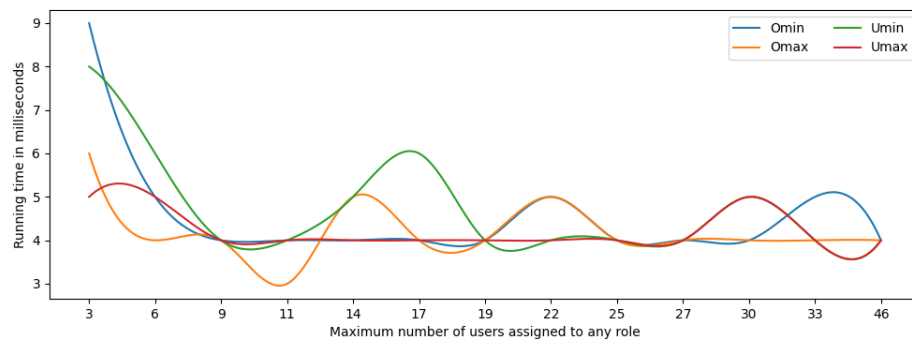


Figure 102: Dataset Healthcare: Running time in milliseconds

9.3 Duplicate Roles Forbidden - small μ value

M	V	1	2	3	4	5
WSC	Omin	1634	1172	963	836	720
	Omax	1634	1060	789	738	692
	Umin	1634	957	770	680	619
	Umax	1634	1056	809	740	689
$ \mathcal{R} $	Omin	74	58	55	52	40
	Omax	74	50	29	25	25
	Umin	74	60	56	49	45
	Umax	74	44	29	27	24
$ \mathcal{UA} $	Omin	74	113	163	197	197
	Omax	74	83	64	58	65
	Umin	74	118	158	180	198
	Umax	74	76	65	66	59
$ \mathcal{PA} $	Omin	1486	1001	744	587	483
	Omax	1486	926	696	653	601
	Umin	1486	777	555	450	376
	Umax	1486	935	714	647	606
$ \mathcal{DUPA} $	Omin	0	0	0	3	9
	Omax	0	1	2	1	5
	Umin	0	0	1	2	1
	Umax	0	0	0	0	0
time	Omin	7	6	6	5	7
	Omax	6	5	4	4	4
	Umin	7	8	5	5	5
	Umax	6	5	4	4	4

Table 45: Experiment's results for dataset Healthcare

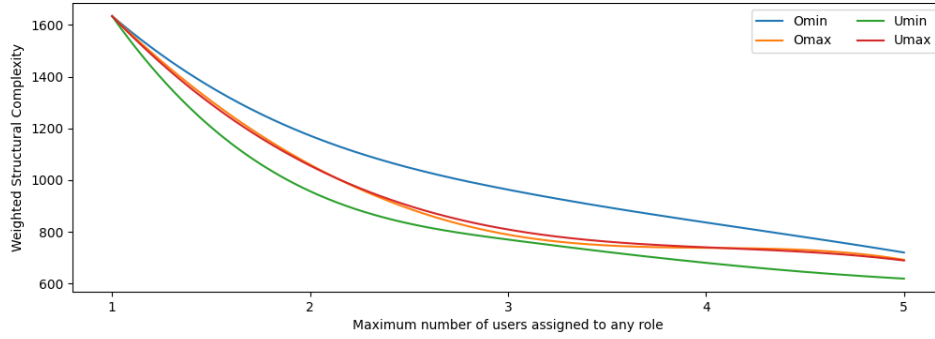


Figure 103: Dataset Healthcare: Weighted Structural Complexity

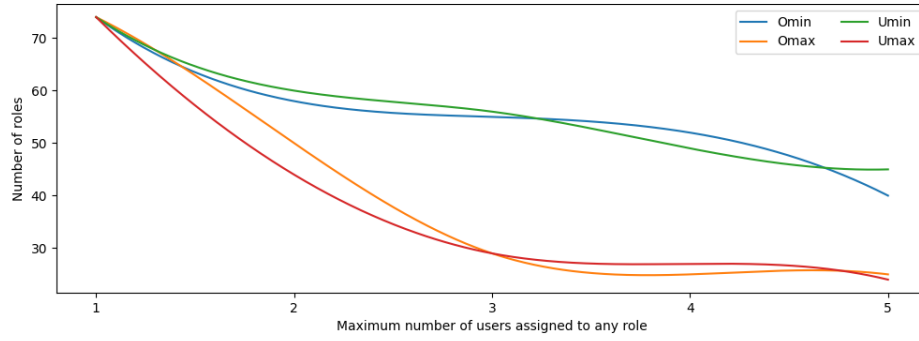


Figure 104: Dataset Healthcare: Number of roles

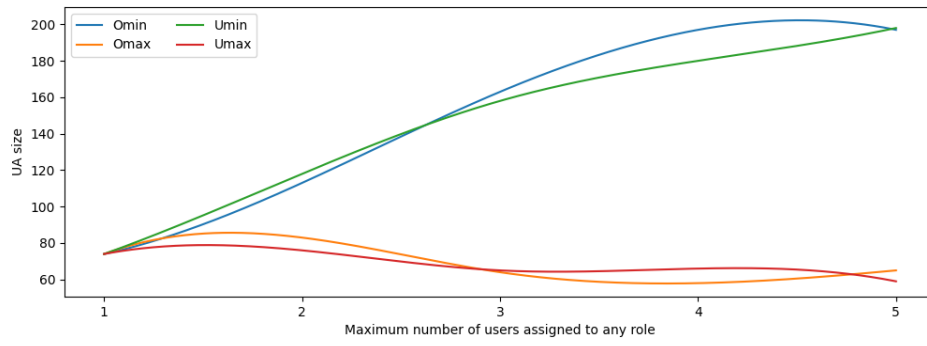


Figure 105: Dataset Healthcare: UA size

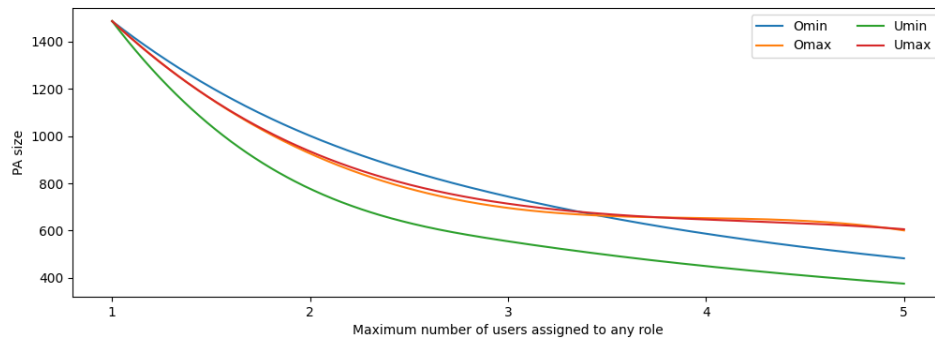


Figure 106: Dataset Healthcare: PA size

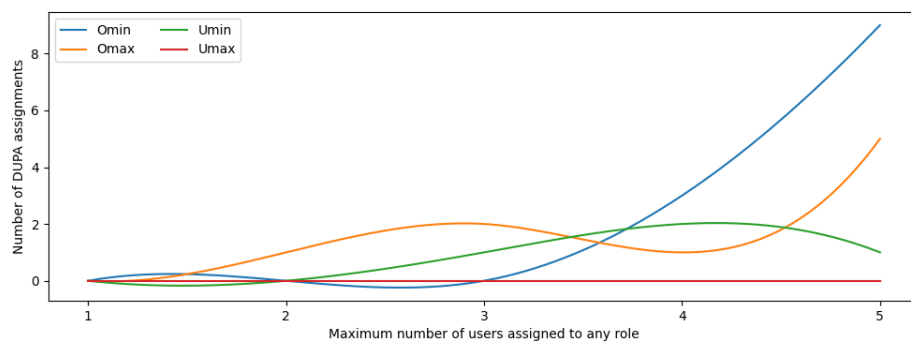


Figure 107: Dataset Healthcare: Number of DIPA assignments

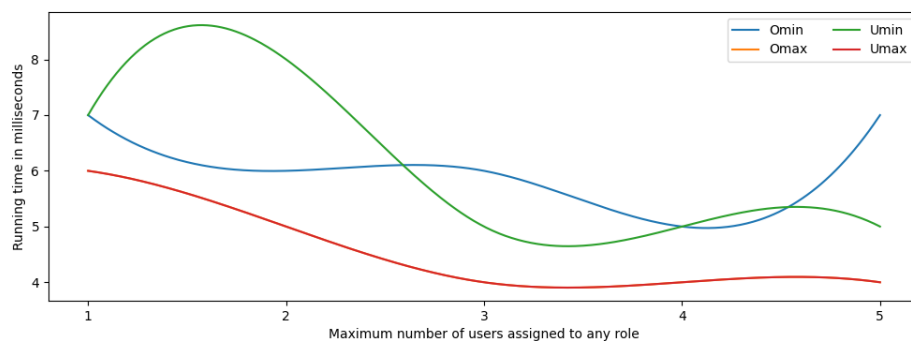


Figure 108: Dataset Healthcare: Running time in milliseconds