**Table 1: Score computation of *TCA* for 2-way CCAG. The running time is measured in CPU second. The cutoff time is set to 1000s**

| Instance | #Score | time | Instance | #Score | time |
|---|---|---|---|---|---|
| apache | 32390056 | 411.95 | Syn_3 | 108289990 | 308.82 |
| bugzilla | 98638822 | 389.24 | Syn_4 | 74584337 | 374.53 |
| gcc | 24990778 | 366.43 | Syn_5 | 25253531 | 382.08 |
| spins | 180757752 | 319.41 | Syn_6 | 64600518 | 423.28 |
| spinv | 59262237 | 242.4 | Syn_7 | 139868612 | 400.69 |
| tcas | 250542312 | 342.82 | Syn_8 | 37304853 | 363.01 |
| Banking1 | 175528367 | 189.96 | Syn_9 | 78916861 | 408.86 |
| Banking2 | 199900441 | 367.37 | Syn_10 | 31677137 | 381.28 |
| CommProtocol | 30660722 | 49.09 | Syn_11 | 45896119 | 362.69 |
| Concurrency | 14782964 | 15.62 | Syn_12 | 32321011 | 385.59 |
| Healthcare1 | 199996275 | 295.77 | Syn_13 | 36068134 | 401.87 |
| Healthcare2 | 151948035 | 249.16 | Syn_14 | 49744135 | 395.57 |
| Healthcare3 | 86817952 | 251.38 | Syn_15 | 64964334 | 336.04 |
| Healthcare4 | 82730093 | 272.74 | Syn_16 | 57893654 | 411.7 |
| Insurance | 357313109 | 608.75 | Syn_17 | 33955673 | 397.46 |
| NetworkMgmt | 179831252 | 246.97 | Syn_18 | 32144767 | 383.27 |
| ProcessorComm1 | 166249296 | 302.54 | Syn_19 | 22412303 | 368.52 |
| ProcessorComm2 | 87019145 | 227.8 | Syn_20 | 29403957 | 383.58 |
| Services | 54508561 | 96.78 | Syn_21 | 56993638 | 405.09 |
| Storage1 | 159684114 | 157.8 | Syn_22 | 59811981 | 403.28 |
| Storage2 | 490820602 | 498.05 | Syn_23 | 135373126 | 366.06 |
| Storage3 | 113974949 | 210.95 | Syn_24 | 39095972 | 379.94 |
| Storage4 | 122046361 | 267.49 | Syn_25 | 33933958 | 372.56 |
| Storage5 | 54112196 | 133.24 | Syn_26 | 47044342 | 372.17 |
| SystemMgmt | 191567109 | 282.32 | Syn_27 | 69761639 | 363.21 |
| Telecom | 200036963 | 290.68 | Syn_28 | 22212050 | 369.48 |
| Syn_1 | 46317309 | 371.27 | Syn_29 | 32983250 | 387.1 |
| Syn_2 | 47779790 | 370.63 | Syn_30 | 60262593 | 395.02 |

**Table 2: Score computation of *TCA* for 3-way CCAG. The running time is measured in CPU second. The cutoff time is set to 1000s**

| Instance | #Score | time | Instance | #Score | time |
|---|---|---|---|---|---|
| apache | 345316 | 811.82 | Syn_3 | 21431034 | 795.34 |
| bugzilla | 8228065 | 888.8 | Syn_4 | 5636246 | 891.39 |
| gcc | 279570 | 724.94 | Syn_5 | 5972 | 738.09 |
| spins | 61266020 | 709.1 | Syn_6 | 3122285 | 908.46 |
| spinv | 7197773 | 859.23 | Syn_7 | 21988255 | 843.71 |
| tcas | 125227971 | 629.2 | Syn_8 | 731100 | 905.34 |
| Banking1 | 187322356 | 276.76 | Syn_9 | 5308377 | 895.46 |
| Banking2 | 73344485 | 703.66 | Syn_10 | 54831 | 863.9 |
| CommProtocol | 40143266 | 225.75 | Syn_11 | 1381147 | 918.77 |
| Concurrency | 217496176 | 290.69 | Syn_12 | 233554 | 869.73 |
| Healthcare1 | 116728874 | 530.87 | Syn_13 | 579250 | 886.13 |
| Healthcare2 | 88495959 | 551.17 | Syn_14 | 1812698 | 915.25 |
| Healthcare3 | 20684921 | 786.52 | Syn_15 | 5250812 | 874.16 |
| Healthcare4 | 14556846 | 829.58 | Syn_16 | 2438428 | 913.5 |
| Insurance | 82953558 | 797.17 | Syn_17 | 363281 | 886.14 |
| NetworkMgmt | 122989332 | 448.05 | Syn_18 | 254876 | 868.92 |
| ProcessorComm1 | 72352806 | 667.84 | Syn_19 | 904 | 554.57 |
| ProcessorComm2 | 25708173 | 732 | Syn_20 | 6590 | 784.3 |
| Services | 39910947 | 315.33 | Syn_21 | 2544516 | 912 |
| Storage1 | 284898747 | 292.69 | Syn_22 | 2988351 | 904.82 |
| Storage2 | 428515632 | 547.46 | Syn_23 | 25697596 | 805.68 |
| Storage3 | 61933558 | 592.37 | Syn_24 | 583917 | 911.68 |
| Storage4 | 38276071 | 716.22 | Syn_25 | 42161 | 890.13 |
| Storage5 | 25135521 | 654 | Syn_26 | 1663221 | 916.39 |
| SystemMgmt | 128287514 | 528.19 | Syn_27 | 4922611 | 892.98 |
| Telecom | 122873676 | 496.07 | Syn_28 | 1227 | 574.18 |
| Syn_1 | 1650424 | 915.79 | Syn_29 | 643408 | 865.58 |
| Syn_2 | 1915583 | 903.06 | Syn_30 | 2967436 | 901.1 |

**Table 3: Score computation of *TCA* for 4-way CCAG. The running time is measured in CPU second. The cutoff time is set to 1000s**

| Instance | #Score | time | Instance | #Score | time |
|---|---|---|---|---|---|
| bugzilla | 7112654 | 889.41 | Storage2 | 427022132 | 547.49 |
| spins | 53693113 | 708.96 | Storage3 | 61952248 | 594.47 |
| spinv | 6247839 | 865.31 | Storage4 | 37878230 | 714.25 |
| tcas | 108643802 | 632.41 | Storage5 | 24515055 | 646.6 |
| Banking1 | 186242700 | 277.29 | SystemMgmt | 123054174 | 528.14 |
| Banking2 | 73630418 | 703.66 | Telecom | 118129489 | 496.35 |
| CommProtocol | 40000105 | 226.41 | Syn_15 | 5383368 | 876.37 |
| Concurrency | 211282196 | 289.88 | Syn_16 | 2519838 | 911.89 |
| Healthcare1 | 114862643 | 529.84 | Syn_21 | 2504700 | 911.28 |
| Healthcare2 | 85733114 | 551.1 | Syn_22 | 3024558 | 904.08 |
| Healthcare3 | 20688012 | 788.08 | Syn_23 | 25484236 | 798.53 |
| Healthcare4 | 14434598 | 829.89 | Syn_27 | 5020471 | 897.08 |
| Insurance | 82906511 | 797.26 | Syn_30 | 2952393 | 904.33 |
| NetworkMgmt | 119237498 | 442.05 | Syn_3 | 21440405 | 795.38 |
| ProcessorComm1 | 72114422 | 667.7 | Syn_4 | 5634093 | 891.66 |
| ProcessorComm2 | 25657392 | 726.2 | Syn_6 | 3131544 | 907.95 |
| Services | 39956530 | 314.11 | Syn_7 | 21793458 | 845.21 |
| Storage1 | 282319131 | 291.28 | Syn_9 | 5320819 | 895.51 |

**Table 4: Comparing *TCA+* with *TCA* for 2-way CCAG. The running time is measured in CPU second. The cutoff time is set to 1000s**

| Instance | *TCA+* | | *TCA* | | $time_r$ |
|---|---|---|---|---|---|
| | min (avg) | time | min (avg) | time | |
| apache | 30(30) | **1.65** | 30(30) | 1.85 | 1.65 |
| bugzilla | 16(16) | 0.02 | 16(16) | **0.01** | 0.02 |
| gcc | 16(16.1) | **289.3** | 16(16.1) | 332.89 | 289.3 |
| spins | 19(19) | **0.15** | 19(19) | 0.16 | 0.15 |
| spinv | **31(32)** | 356.91 | 32(32.2) | 264.38 | 254.42 |
| tcas | 100(100) | < 0.01 | 100(100) | < 0.01 | < 0.01 |
| Banking1 | 13(13) | < 0.01 | 13(13) | < 0.01 | < 0.01 |
| Banking2 | 10(10) | < 0.01 | 10(10) | < 0.01 | < 0.01 |
| CommProtocol | 16(16) | < 0.01 | 16(16) | < 0.01 | < 0.01 |
| Concurrency | 5(5) | < 0.01 | 5(5) | < 0.01 | < 0.01 |
| Healthcare1 | 30(30) | < 0.01 | 30(30) | < 0.01 | < 0.01 |
| Healthcare2 | 14(14) | **0.02** | 14(14) | 0.08 | 0.02 |
| Healthcare3 | 34(34) | **0.47** | 34(34) | 0.53 | 0.47 |
| Healthcare4 | 46(46) | **1.73** | 46(46) | 2.11 | 1.73 |
| Insurance | 527(527) | < 0.01 | 527(527) | < 0.01 | < 0.01 |
| NetworkMgmt | 110(110) | < 0.01 | 110(110) | < 0.01 | < 0.01 |
| ProcessorComm1 | 22(22) | **2.59** | 22(22) | 2.89 | 2.59 |
| ProcessorComm2 | 25(25) | 1.05 | 25(25) | **1.04** | 1.05 |
| Services | 100(100.1) | **334.71** | 100(100.1) | 347.38 | 334.71 |
| Storage1 | 17(17) | < 0.01 | 17(17) | < 0.01 | < 0.01 |
| Storage2 | 18(18) | < 0.01 | 18(18) | < 0.01 | < 0.01 |
| Storage3 | 50(50) | **0.03** | 50(50) | 0.13 | 0.03 |
| Storage4 | 130(130) | **0.01** | 130(130) | 0.03 | 0.01 |
| Storage5 | 215(215) | **0.72** | 215(215) | 0.81 | 0.72 |
| SystemMgmt | 15(15) | < 0.01 | 15(15) | < 0.01 | < 0.01 |
| Telecom | 30(30) | < 0.01 | 30(30) | < 0.01 | < 0.01 |
| Syn_1 | 36(36) | **93.33** | 36(36) | 125.16 | 93.33 |
| Syn_2 | 30(30) | **1.06** | 30(30) | 1.53 | 1.06 |
| Syn_3 | 18(18) | < 0.01 | 18(18) | < 0.01 | < 0.01 |
| Syn_4 | 20(20) | **0.03** | 20(20) | 0.04 | 0.03 |
| Syn_5 | 43(**43**) | 326.28 | 43(43.2) | 239.54 | 170.51 |
| Syn_6 | 24(24) | **0.05** | 24(24) | 0.07 | 0.05 |
| Syn_7 | 9(9) | < 0.01 | 9(9) | < 0.01 | < 0.01 |
| Syn_8 | 37(37) | **139.57** | 37(37) | 182.57 | 139.57 |
| Syn_9 | 20(20) | **0.02** | 20(20) | 0.04 | 0.02 |
| Syn_10 | 39(**39.7**) | 229.41 | 39(39.9) | 81.87 | 58.23 |
| Syn_11 | 38(**38.7**) | 186 | 38(38.8) | 113.96 | 86.32 |
| Syn_12 | 36(36) | **8.99** | 36(36) | 12.71 | 8.99 |
| Syn_13 | 36(36) | **0.82** | 36(36) | 0.93 | 0.82 |
| Syn_14 | 36(36) | **0.42** | 36(36) | 0.59 | 0.42 |
| Syn_15 | 30(30) | **0.36** | 30(30) | 0.56 | 0.36 |
| Syn_16 | 24(24) | **0.13** | 24(24) | 0.14 | 0.13 |
| Syn_17 | 36(36) | **9.07** | 36(36) | 12.94 | 9.07 |
| Syn_18 | 39(39.7) | **141.91** | 39(39.7) | 195.56 | 141.91 |
| Syn_19 | 43(43.7) | **114** | 43(43.7) | 153.85 | 114 |
| Syn_20 | 49(49.9) | **111.29** | 49(49.9) | 162.21 | 111.29 |
| Syn_21 | 36(36) | **0.18** | 36(36) | 0.31 | 0.18 |
| Syn_22 | 36(36) | **0.1** | 36(36) | 0.13 | 0.1 |
| Syn_23 | 12(12) | < 0.01 | 12(12) | < 0.01 | < 0.01 |
| Syn_24 | 39(40) | **282.35** | 39(40) | 374.46 | 282.35 |
| Syn_25 | 45(**45.3**) | 441.73 | 45(45.7) | 147.91 | 107.22 |
| Syn_26 | 27(27) | **104.14** | 27(27) | 132.52 | 104.14 |
| Syn_27 | 36(36) | 0.06 | 36(36) | 0.06 | 0.06 |
| Syn_28 | 47(47) | **195.2** | 47(47) | 273.92 | 195.2 |
| Syn_29 | 25(25) | **4.53** | 25(25) | 6.12 | 4.53 |
| Syn_30 | 16(16) | **99.14** | 16(16) | 122.47 | 99.14 |

**Table 5: Comparing *TCA+* with *TCA* for 3-way CCAG. The running time is measured in CPU second. The cutoff time is set to 1000s**

| Instance | *TCA+* | | *TCA* | | $time_r$ |
|---|---|---|---|---|---|
| | min (avg) | time | min (avg) | time | |
| apache | **144(145.4)** | 786.99 | 154(156.1) | 871.68 | 212.57 |
| bugzilla | 48(48) | **2.45** | 48(48) | 9.96 | 2.45 |
| gcc | **77(79.4)** | 522.88 | 82(83.6) | 802.79 | 310.79 |
| spins | 80(80) | **1.31** | 80(80) | 3.55 | 1.31 |
| spinv | 198(200.2) | **23.38** | 198(200.2) | 152.27 | 23.38 |
| tcas | 400(400) | **0.03** | 400(400) | 0.1 | 0.03 |
| Banking1 | 45(45) | 0.28 | 45(45) | 0.28 | 0.28 |
| Banking2 | 30(30) | < 0.01 | 30(30) | < 0.01 | < 0.01 |
| CommProtocol | 41(41) | **1.25** | 41(41) | 1.4 | 1.25 |
| Concurrency | 8(8) | < 0.01 | 8(8) | < 0.01 | < 0.01 |
| Healthcare1 | 96(96) | **0.03** | 96(96) | 0.04 | 0.03 |
| Healthcare2 | **51(51.9)** | 153.7 | 52(52) | 129.18 | 80.29 |
| Healthcare3 | **153(154.4)** | 236.42 | 154(154.8) | 283.19 | 80.53 |
| Healthcare4 | **239(239.7)** | 505.01 | 240(241.2) | 651.75 | 145.7 |
| Insurance | 6851(6851) | **2.3** | 6851(6851) | 10.07 | 2.3 |
| NetworkMgmt | 1100(1100) | **0.28** | 1100(1100) | 0.55 | 0.28 |
| ProcessorComm1 | **106(108)** | 336.58 | 108(108.5) | 273.86 | 151.97 |
| ProcessorComm2 | 126(**126.5**) | 285.47 | 126(126.6) | 516.91 | 218.1 |
| Services | 842(848.5) | **174.58** | 842(848.5) | 218.69 | 174.58 |
| Storage1 | 25(25) | < 0.01 | 25(25) | < 0.01 | < 0.01 |
| Storage2 | 54(54) | < 0.01 | 54(54) | < 0.01 | < 0.01 |
| Storage3 | 222(222) | **3.53** | 222(222) | 7.68 | 3.53 |
| Storage4 | 910(910) | **10.58** | 910(910) | 34.68 | 10.58 |
| Storage5 | **1708(1709.7)** | 658.86 | 1710(1712.3) | 796.41 | 327.39 |
| SystemMgmt | 45(45) | **0.64** | 45(45) | 0.88 | 0.64 |
| Telecom | 120(120) | **0.07** | 120(120) | 0.12 | 0.07 |
| Syn_1 | **249(251.6)** | 487.89 | 254(255.6) | 847.41 | 78.52 |
| Syn_2 | **139(140.4)** | 414.98 | 141(143.7) | 469.11 | 56.9 |
| Syn_3 | 51(51) | **9.38** | 51(51) | 37.39 | 9.38 |
| Syn_4 | 80(80) | **7.13** | 80(80) | 40.02 | 7.13 |
| Syn_5 | **335(337.2)** | 790.34 | 410(413.9) | 991.75 | 301.11 |
| Syn_6 | 96(96) | **17.63** | 96(96) | 137.35 | 17.63 |
| Syn_7 | 25(**25**) | 230.22 | 25(25.3) | 353.54 | 81.21 |
| Syn_8 | **262(263.1)** | 643.76 | 268(270.9) | 873.29 | 95.64 |
| Syn_9 | 60(60) | **2.69** | 60(60) | 8.09 | 2.69 |
| Syn_10 | **288(292)** | 546.12 | 323(329) | 992.58 | 152.94 |
| Syn_11 | **279(280.2)** | 410.68 | 284(285.5) | 909.77 | 82.81 |
| Syn_12 | **217(218.8)** | 645.2 | 237(238.8) | 980.72 | 145.76 |
| Syn_13 | 180(**180**) | 151.61 | 180(181.7) | 732.81 | 106 |
| Syn_14 | 216(216) | **27.5** | 216(216) | 159.48 | 27.5 |
| Syn_15 | 150(150) | **18.37** | 150(150) | 117.57 | 18.37 |
| Syn_16 | 96(96) | **16.29** | 96(96) | 98.77 | 16.29 |
| Syn_17 | **218(219)** | 580.21 | 228(230.7) | 923.09 | 124.63 |
| Syn_18 | **289(291.6)** | 459.05 | 301(303.8) | 971.85 | 143.27 |
| Syn_19 | **332(335.3)** | 743.75 | 486(492.4) | 989.92 | 498.84 |
| Syn_20 | **415(418.4)** | 752.5 | 501(511.6) | 991.69 | 232.06 |
| Syn_21 | 216(216) | **15.96** | 216(216) | 88.39 | 15.96 |
| Syn_22 | 144(144) | **10.77** | 144(144) | 45.96 | 10.77 |
| Syn_23 | 36(36) | **1.16** | 36(36) | 4.49 | 1.16 |
| Syn_24 | **293(295.4)** | 489.29 | 299(303.1) | 919.7 | 92.75 |
| Syn_25 | **360(362.8)** | 596.54 | 393(395) | 993.33 | 129.26 |
| Syn_26 | **164(165.9)** | 538.64 | 167(169.5) | 773.54 | 74.21 |
| Syn_27 | 180(180) | **7.32** | 180(180) | 45.08 | 7.32 |
| Syn_28 | **380(383.7)** | 856.02 | 503(506.5) | 989.24 | 479.19 |
| Syn_29 | 125(**125**) | 146.94 | 125(125.4) | 708.87 | 126.15 |
| Syn_30 | **68(68.7)** | 353.31 | 69(69.7) | 432.07 | 52.66 |

**Table 6: Comparing *FastCA* against state-of-the-art competitors for 2-way CCAG. The running time is measured in CPU second.**

| Instance | *FastCA (1000s)* | | *FastCA (100s)* | | *TCA (1000s)* | | *ACTS (1000s)* | | *HHSA (1000s)* | | *CASA (1000s)* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | min (avg) | time | min (avg) | time | min (avg) | time | min | time | min (avg) | time | min (avg) | time |
| apache | **30**(**30**) | 1.34 | **30**(**30**) | 1.34 | **30**(**30**) | 1.85 | 33(33) | 0.57 | **30**(30.7) | 267.34 | 32(34.6) | 4.11 |
| bugzilla | **16**(**16**) | 0.52 | **16**(**16**) | 0.52 | **16**(**16**) | 0.01 | 19(19) | 0.3 | **16**(**16**) | 11.77 | **16**(16.4) | 0.2 |
| gcc | **16**(**16**) | 246.29 | **16**(16.6) | 9.09 | **16**(16.1) | 332.89 | 23(23) | 0.64 | 18(18.5) | 296.54 | 19(22.1) | 76.8 |
| spins | **19**(**19**) | 0.63 | **19**(**19**) | 0.63 | **19**(**19**) | 0.16 | 26(26) | 0.34 | **19**(**19**) | 16.23 | **19**(19.8) | 0.16 |
| spinv | **31**(**31**) | 30.06 | **31**(**31**) | 30.06 | 32(32.2) | 264.38 | 45(45) | 0.55 | **31**(31.2) | 115.31 | 36(40.2) | 3.11 |
| tcas | 100(100) | 0.22 | 100(100) | 0.22 | 100(100) | **<0.01** | 100(100) | 0.28 | 100(100) | 13.28 | 100(100) | 0.01 |
| Banking1 | **13**(**13**) | 3.78 | **13**(**13**) | 3.78 | **13**(**13**) | < 0.01 | 15(15) | 0.9 | **13**(**13**) | 17.75 | **13**(13.2) | < 0.01 |
| Banking2 | **10**(**10**) | 0.39 | **10**(**10**) | 0.39 | **10**(**10**) | < 0.01 | 11(11) | 0.3 | **10**(**10**) | < 0.01 | **10**(10.1) | 0.01 |
| CommProto. | **16**(**16**) | 5.9 | **16**(**16**) | 5.9 | **16**(**16**) | < 0.01 | 19(19) | 1.27 | **16**(**16**) | 72.92 | **16**(**16**) | 0.01 |
| Concurrency | **5**(**5**) | 0.5 | **5**(**5**) | 0.5 | **5**(**5**) | < 0.01 | 6(6) | 0.27 | **5**(**5**) | < 0.01 | **5**(**5**) | < 0.01 |
| Healthcare1 | 30(**30**) | 0.55 | 30(**30**) | 0.55 | 30(**30**) | < 0.01 | 30(**30**) | 0.61 | 30(**30**) | 5.19 | 30(30.1) | < 0.01 |
| Healthcare2 | **14**(**14**) | 1.73 | **14**(**14**) | 1.73 | **14**(**14**) | 0.08 | 16(16) | 1.63 | **14**(**14**) | 11.32 | **14**(14.9) | 0.02 |
| Healthcare3 | **34**(**34**) | 1.32 | **34**(**34**) | 1.32 | **34**(**34**) | 0.53 | 38(38) | 0.98 | **34**(**34**) | 20.32 | **34**(35.5) | 0.23 |
| Healthcare4 | **46**(**46**) | 1.08 | **46**(**46**) | 1.08 | **46**(**46**) | 2.11 | 49(49) | 0.66 | **46**(**46**) | 20.7 | **46**(47) | 0.47 |
| Insurance | 527(**527**) | 0.31 | 527(**527**) | 0.31 | 527(**527**) | < 0.01 | 527(**527**) | 0.11 | 527(**527**) | 151.33 | 527(540.3) | 3.68 |
| NetworkMg. | **110**(**110**) | 0.58 | **110**(**110**) | 0.58 | **110**(**110**) | < 0.01 | 112(112) | 0.56 | **110**(**110**) | 11.76 | **110**(116.3) | 0.88 |
| Proc.Comm1 | **21**(**21.9**) | 33.35 | **22**(**22**) | 1.08 | 22(22) | 2.89 | 29(29) | 0.55 | 22(22) | 4.13 | 22(24.1) | 0.51 |
| Proc.Comm2 | **25**(**25**) | 2.33 | **25**(**25**) | 2.33 | **25**(**25**) | 1.04 | 32(32) | 1.52 | **25**(26) | 23.65 | 26(27.7) | 0.25 |
| Services | **100**(**100**) | 17.49 | **100**(**100**) | 17.49 | **100**(100.1) | 347.38 | 106(106) | 9.77 | **100**(**100**) | 30.99 | 102(104.8) | 0.99 |
| Storage1 | 17(**17**) | 1.8 | 17(**17**) | 1.8 | 17(**17**) | < 0.01 | 17(**17**) | 1.65 | 17(**17**) | 32.76 | 17(17.1) | < 0.01 |
| Storage2 | 18(18) | 0.06 | 18(18) | 0.06 | 18(18) | **<0.01** | 18(18) | 0.04 | 18(18) | 11.63 | 18(18) | **<0.01** |
| Storage3 | 50(**50**) | 2.05 | 50(**50**) | 2.05 | 50(**50**) | 0.13 | 50(**50**) | 1.42 | 50(**50**) | 13.64 | 50(51.6) | 0.02 |
| Storage4 | **130**(**130**) | 0.67 | **130**(**130**) | 0.67 | **130**(**130**) | 0.03 | 136(136) | 0.6 | **130**(**130**) | 16.12 | **130**(130.5) | 0.43 |
| Storage5 | **215**(**215**) | 3.68 | **215**(**215**) | 3.68 | **215**(**215**) | 0.81 | 218(218) | 2 | **215**(**215**) | 125.73 | **215**(221.3) | 13.53 |
| SystemMg. | **15**(**15**) | 0.5 | **15**(**15**) | 0.5 | **15**(**15**) | < 0.01 | 17(17) | 0.54 | **15**(**15**) | 3.4 | **15**(16.1) | < 0.01 |
| Telecom | **30**(**30**) | 0.81 | **30**(**30**) | 0.81 | **30**(**30**) | < 0.01 | 32(32) | 0.66 | **30**(**30**) | 4.41 | **30**(30.2) | < 0.01 |
| Syn_1 | **36**(**36**) | 3.24 | **36**(**36**) | 3.24 | **36**(**36**) | 125.16 | 48(48) | 1.49 | 37(37.1) | 251.53 | 38(40.1) | 13.17 |
| Syn_2 | **30**(**30**) | 1.21 | **30**(**30**) | 1.21 | **30**(**30**) | 1.53 | 32(32) | 1.08 | **30**(**30**) | 56.59 | **30**(31.8) | 1.96 |
| Syn_3 | **18**(**18**) | 0.72 | **18**(**18**) | 0.72 | **18**(**18**) | < 0.01 | 19(19) | 0.8 | **18**(**18**) | 12.13 | **18**(18.6) | 0.01 |
| Syn_4 | **20**(**20**) | 0.6 | **20**(**20**) | 0.6 | **20**(**20**) | 0.04 | 22(22) | 1.04 | **20**(**20**) | < 0.01 | **20**(21.9) | 0.41 |
| Syn_5 | **42**(**42.6**) | 215.32 | **43**(**43**) | 20.23 | 43(43.2) | 239.54 | 54(54) | 1.89 | 46(46.6) | 395.25 | 45(50.1) | 69.35 |
| Syn_6 | **24**(**24**) | 0.74 | **24**(**24**) | 0.74 | **24**(**24**) | 0.07 | 25(25) | 1.36 | **24**(**24**) | 108.81 | **24**(24.2) | 0.57 |
| Syn_7 | **9**(**9**) | 0.3 | **9**(**9**) | 0.3 | **9**(**9**) | < 0.01 | 12(12) | 0.81 | **9**(**9**) | 42.98 | **9**(**9**) | 0.01 |
| Syn_8 | **36**(**36**) | 33.65 | **36**(**36**) | 33.65 | 37(37) | 182.57 | 47(47) | 1.66 | 37(38.5) | 403.01 | 38(41.5) | 22.5 |
| Syn_9 | **20**(**20**) | 1.4 | **20**(**20**) | 1.4 | **20**(**20**) | 0.04 | 22(22) | 1.36 | **20**(**20**) | < 0.01 | **20**(20.2) | 0.28 |
| Syn_10 | **38**(**38.1**) | 190.81 | **38**(**38.5**) | 32.19 | 39(39.9) | 81.87 | 47(47) | 1.92 | 43(43.7) | 338.67 | 42(44.2) | 31.05 |
| Syn_11 | **37**(**37.6**) | 146.3 | **37**(**37.8**) | 35.32 | 38(38.8) | 113.96 | 47(47) | 1.78 | 41(41.6) | 61.24 | 41(43.3) | 18.09 |
| Syn_12 | **36**(**36**) | 2.31 | **36**(**36**) | 2.31 | **36**(**36**) | 12.71 | 43(43) | 1.5 | **36**(37.4) | 632.82 | 39(41.7) | 18.54 |
| Syn_13 | **36**(**36**) | 1.21 | **36**(**36**) | 1.21 | **36**(**36**) | 0.93 | 40(40) | 1.19 | **36**(**36**) | 445.69 | **36**(37.6) | 4.84 |
| Syn_14 | **36**(**36**) | 1.13 | **36**(**36**) | 1.13 | **36**(**36**) | 0.59 | 39(39) | 0.81 | **36**(36.1) | 191.42 | 37(38.2) | 4 |
| Syn_15 | **30**(**30**) | 1.26 | **30**(**30**) | 1.26 | **30**(**30**) | 0.56 | 32(32) | 1.54 | **30**(**30**) | 26.58 | **30**(31.9) | 0.45 |
| Syn_16 | **24**(**24**) | 1.46 | **24**(**24**) | 1.46 | **24**(**24**) | 0.14 | 25(25) | 1.65 | **24**(**24**) | 118.1 | **24**(24.8) | 0.75 |
| Syn_17 | **36**(**36**) | 2.72 | **36**(**36**) | 2.72 | **36**(**36**) | 12.94 | 41(41) | 1.25 | 37(37.1) | 398.17 | 38(40.5) | 10.89 |
| Syn_18 | **38**(**38**) | 119.29 | **38**(**38.3**) | 28.05 | 39(39.7) | 195.56 | 52(52) | 1.17 | 41(41.6) | 179.53 | 41(42.4) | 27.5 |
| Syn_19 | **41**(**41.7**) | 111.01 | **41**(**41.8**) | 30.13 | 43(43.7) | 153.85 | 51(51) | 2.45 | 45(46.5) | 532.6 | 47(49.4) | 40.74 |
| Syn_20 | **49**(**49**) | 67.26 | **49**(**49.1**) | 26.44 | **49**(49.9) | 162.21 | 60(60) | 2.07 | 52(53.3) | 725.59 | 52(53.4) | 121.53 |
| Syn_21 | **36**(**36**) | 1.22 | **36**(**36**) | 1.22 | **36**(**36**) | 0.31 | 39(39) | 1.81 | **36**(**36**) | 263.54 | **36**(36.6) | 2.73 |
| Syn_22 | **36**(**36**) | 0.97 | **36**(**36**) | 0.97 | **36**(**36**) | 0.13 | 37(37) | 1.08 | **36**(**36**) | 194.2 | **36**(**36**) | 0.56 |
| Syn_23 | **12**(**12**) | 0.56 | **12**(**12**) | 0.56 | **12**(**12**) | < 0.01 | 14(14) | 0.66 | **12**(12.1) | 4.3 | **12**(12.7) | 0.02 |
| Syn_24 | **38**(**38**) | 188.25 | **38**(**38.6**) | 22.06 | 39(40) | 374.46 | 48(48) | 1.66 | 41(42.3) | 147.69 | 42(43.1) | 32.77 |
| Syn_25 | **44**(**44**) | 91.07 | **44**(**44.3**) | 24.59 | 45(45.7) | 147.91 | 52(52) | 1.64 | 47(47.9) | 303.78 | 47(48) | 118.76 |
| Syn_26 | **26**(**26.8**) | 152.81 | **27**(**27**) | 6.87 | 27(27) | 132.52 | 34(34) | 1.72 | 28(29.7) | 142.36 | 30(32.9) | 2.86 |
| Syn_27 | **36**(**36**) | 1.5 | **36**(**36**) | 1.5 | **36**(**36**) | 0.06 | 37(37) | 1.09 | **36**(**36**) | 76.89 | **36**(36.6) | 0.39 |
| Syn_28 | **46**(**46**) | 24.88 | **46**(**46**) | 24.88 | 47(47) | 273.92 | 57(57) | 1.7 | 50(50.6) | 326.67 | 50(51.4) | 78.78 |
| Syn_29 | **25**(**25**) | 2.32 | **25**(**25**) | 2.32 | **25**(**25**) | 6.12 | 29(29) | 1.44 | 26(27.4) | 320.92 | 29(30.7) | 3.37 |
| Syn_30 | **16**(**16**) | 6.69 | **16**(**16**) | 6.69 | **16**(**16**) | 122.47 | 22(22) | 1.07 | 17(17.9) | 72.77 | 19(19.7) | 0.92 |

**Table 7: Comparing *FastCA* against state-of-the-art competitors for 3-way CCAG. The running time is measured in CPU second.**

| Instance | *FastCA (1000s)* | | *FastCA (100s)* | | *TCA (1000s)* | | *ACTS (1000s)* | | *HHSA (1000s)* | | *CASA (1000s)* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | min (avg) | time | min (avg) | time | min (avg) | time | min | time | min (avg) | time | min (avg) | time |
| apache | **133(134.7)** | 716.77 | **141(142.7)** | 79.12 | 154(156.1) | 871.68 | 173(173) | 7.92 | – | > 1000 | 245(247.9) | 920.36 |
| bugzilla | **48(48)** | 17.35 | **48(48)** | 17.35 | **48(48)** | 9.96 | 68(68) | 0.44 | 60(60.9) | 481.54 | 61(64.6) | 36.38 |
| gcc | **75(76.8)** | 561.74 | **79(80.6)** | 75.44 | 82(83.6) | 802.79 | 108(108) | 9.48 | – | > 1000 | 134(140) | 943.47 |
| spins | **80(80)** | 1.17 | **80(80)** | 1.17 | **80(80)** | 3.55 | 98(98) | 0.37 | **80**(85.7) | 59.55 | 94(100.5) | 7.14 |
| spinv | **195(196)** | 415.45 | **196(197.4)** | 65.26 | 198(200.2) | 152.27 | 286(286) | 1.27 | – | > 1000 | 224(233.1) | 734.92 |
| tcas | **400(400)** | 0.47 | **400(400)** | 0.47 | **400(400)** | 0.1 | 405(405) | 0.32 | **400(400)** | 337.88 | **400**(404.1) | 4.27 |
| Banking1 | **45(45)** | 4.1 | **45(45)** | 4.1 | **45(45)** | 0.28 | 58(58) | 2.07 | **45(45)** | 9.9 | **45**(46.2) | 0.09 |
| Banking2 | **30(30)** | 0.66 | **30(30)** | 0.66 | **30(30)** | < 0.01 | 39(39) | 0.44 | **30(30)** | 1.1 | **30**(30.4) | 0.35 |
| CommProto. | **41(41)** | 16.68 | **41(41)** | 16.68 | **41(41)** | 1.4 | 49(49) | 3.22 | **41(41)** | 76.93 | **41**(42.2) | 0.25 |
| Concurrency | 8(8) | 0.31 | 8(8) | 0.31 | 8(8) | **<0.01** | 8(8) | 0.51 | 8(8) | 7.51 | 8(8) | **<0.01** |
| Healthcare1 | **96(96)** | 0.8 | **96(96)** | 0.8 | **96(96)** | 0.04 | 105(105) | 0.65 | **96(96)** | 53.61 | **96**(96.6) | 0.3 |
| Healthcare2 | **50(50.9)** | 225.47 | **50(51.4)** | 26.74 | 52(52) | 129.18 | 67(67) | 1.26 | 51(52.1) | 23.5 | 53(55.1) | 6.16 |
| Healthcare3 | **151(151.5)** | 325.85 | **151(152.4)** | 48.69 | 154(154.8) | 283.19 | 209(209) | 0.92 | 177(186.9) | 373.89 | 170(175) | 237.96 |
| Healthcare4 | **238(239)** | 417.3 | **240(240.7)** | 56.61 | 240(241.2) | 651.75 | 294(294) | 1.21 | 320(346.667) | 725.21 | 278(286.7) | 835.15 |
| Insurance | **6851(6851)** | 1.74 | **6851(6851)** | 1.74 | **6851(6851)** | 10.07 | 6866(6866) | 0.54 | – | > 1000 | 7027(7156.4) | 770.29 |
| NetworkMg. | **1100(1100)** | 1.14 | **1100(1100)** | 1.14 | **1100(1100)** | 0.55 | 1125(1125) | 0.59 | **1100(1100)** | 440.68 | 1124(1136.8) | 5.72 |
| Proc.Comm1 | **104(104.8)** | 160.59 | **105(105.3)** | 32.23 | 108(108.5) | 273.86 | 163(163) | 0.63 | 114(117.6) | 90.78 | 117(120.7) | 111.51 |
| Proc.Comm2 | **125(125.6)** | 189.36 | **125(126.2)** | 53.8 | 126(126.6) | 516.91 | 161(161) | 1.64 | 140(148.2) | 572.5 | 140(145) | 236.73 |
| Services | **813(815.2)** | 685.53 | **829(834.2)** | 81.4 | 842(848.5) | 218.69 | 963(963) | 10.35 | 840(860) | 789.42 | 856(894) | 464.39 |
| Storage1 | 25(25) | 2.05 | 25(25) | 2.05 | 25(25) | **<0.01** | 25(25) | 1.52 | 25(25) | 15.53 | 25(25) | **<0.01** |
| Storage2 | **54(54)** | 0.09 | **54(54)** | 0.09 | **54(54)** | < 0.01 | 74(74) | 0.03 | **54(54)** | 15.9 | **54**(55.8) | 0.02 |
| Storage3 | **222(222)** | 3.43 | **222(222)** | 3.43 | **222(222)** | 7.68 | 239(239) | 1.54 | 224(225.1) | 675.16 | 241(245.8) | 1.83 |
| Storage4 | **910(910)** | 3.62 | **910(910)** | 3.62 | **910(910)** | 34.68 | 990(990) | 0.76 | 960(960) | 853.39 | 926(951.6) | 723.84 |
| Storage5 | **1705(1706.9)** | 445.17 | **1707(1710.3)** | 72.44 | 1710(1712.3) | 796.41 | 1879(1879) | 2.93 | – | > 1000 | 1877(1958.3) | 971.23 |
| SystemMg. | **45(45)** | 1.65 | **45(45)** | 1.65 | **45(45)** | 0.88 | 60(60) | 0.49 | **45**(45.2) | 16.6 | 47(48.3) | 0.3 |
| Telecom | **120(120)** | 0.57 | **120(120)** | 0.57 | **120(120)** | 0.12 | 126(126) | 0.53 | **120(120)** | 12.4 | **120**(120.4) | 0.37 |
| Syn_1 | **243(244.6)** | 471.01 | **247(248.3)** | 81.69 | 254(255.6) | 847.41 | 293(293) | 3.3 | – | > 1000 | 358(366.3) | 899.32 |
| Syn_2 | **133(134)** | 498.59 | **136(138)** | 72.75 | 141(143.7) | 469.11 | 174(174) | 1.67 | – | > 1000 | 174(182.8) | 800.84 |
| Syn_3 | **51(51)** | 7.18 | **51(51)** | 7.18 | **51(51)** | 37.39 | 71(71) | 0.36 | 59(59.5) | 146.55 | 59(61.1) | 2.76 |
| Syn_4 | **80(80)** | 5.49 | **80(80)** | 5.49 | **80(80)** | 40.02 | 102(102) | 0.72 | 100(101.667) | 560.71 | 96(103.6) | 88.82 |
| Syn_5 | **330(332)** | 573.81 | **338(339.3)** | 87.73 | 410(413.9) | 991.75 | 386(386) | 13.76 | – | > 1000 | 1068(1069.25) | 947.22 |
| Syn_6 | **96(96)** | 10.36 | **96(96)** | 10.36 | **96(96)** | 137.35 | 119(119) | 1.22 | – | > 1000 | 118(122.6) | 624.67 |
| Syn_7 | **25(25)** | 23.34 | **25(25.1)** | 13.27 | **25**(25.3) | 353.54 | 35(35) | 0.44 | 26(26.3) | 107.35 | 27(27.8) | 4.91 |
| Syn_8 | **256(257.5)** | 479.04 | **260(262.4)** | 89.28 | 268(270.9) | 873.29 | 326(326) | 4.18 | – | > 1000 | 389(402.5) | 962.69 |
| Syn_9 | **60(60)** | 4.83 | **60(60)** | 4.83 | **60(60)** | 8.09 | 84(84) | 0.81 | 80(80) | 0.14 | 70(76.6) | 384.72 |
| Syn_10 | **277(280.5)** | 520.4 | **287(288.9)** | 93.92 | 323(329) | 992.58 | 329(329) | 9.42 | – | > 1000 | 795(798.1) | 947.41 |
| Syn_11 | **270(271.8)** | 338.9 | **272(274.6)** | 62.37 | 284(285.5) | 909.77 | 318(318) | 3.79 | – | > 1000 | 396(408.8) | 870.45 |
| Syn_12 | **216(216)** | 214.18 | **217(217.9)** | 84.54 | 237(238.8) | 980.72 | 263(263) | 6.94 | – | > 1000 | 367(390.5) | 953.29 |
| Syn_13 | **180(180)** | 32.35 | **180(180)** | 32.35 | **180**(181.7) | 732.81 | 200(200) | 5.45 | – | > 1000 | 277(290.7) | 944.55 |
| Syn_14 | **216(216)** | 9.24 | **216(216)** | 9.24 | **216(216)** | 159.48 | 244(244) | 2.69 | – | > 1000 | 261(270.4) | 885.73 |
| Syn_15 | **150(150)** | 7.56 | **150(150)** | 7.56 | **150(150)** | 117.57 | 173(173) | 1.97 | – | > 1000 | 165(169.2) | 542.73 |
| Syn_16 | **96(96)** | 23.97 | **96(96)** | 23.97 | **96(96)** | 98.77 | 117(117) | 2.58 | – | > 1000 | 119(123.5) | 756.91 |
| Syn_17 | **216(216.1)** | 429.06 | **216(218.9)** | 77.1 | 228(230.7) | 923.09 | 265(265) | 6.39 | – | > 1000 | 338(351.9) | 929.21 |
| Syn_18 | **280(282)** | 521.37 | **284(287.6)** | 88.85 | 301(303.8) | 971.85 | 344(344) | 7.24 | – | > 1000 | 446(449) | 931.68 |
| Syn_19 | **316(318)** | 527.65 | **330(331.7)** | 96.81 | 486(492.4) | 989.92 | 373(373) | 21.58 | – | > 1000 | – | > 1000 |
| Syn_20 | **411(412.1)** | 623.28 | **418(421.2)** | 94.78 | 501(511.6) | 991.69 | 463(463) | 12.82 | – | > 1000 | 1026(1050.9) | 873.88 |
| Syn_21 | **216(216)** | 7.39 | **216(216)** | 7.39 | **216(216)** | 88.39 | 235(235) | 3.05 | – | > 1000 | 243(250.1) | 956.52 |
| Syn_22 | **144(144)** | 5.15 | **144(144)** | 5.15 | **144(144)** | 45.96 | 164(164) | 2.07 | – | > 1000 | 162(170.7) | 521.59 |
| Syn_23 | **36(36)** | 2.62 | **36(36)** | 2.62 | **36(36)** | 4.49 | 48(48) | 1.02 | 38(39.5) | 155.17 | 37(39.2) | 2.68 |
| Syn_24 | **284(285.7)** | 430.78 | **286(290.1)** | 88.37 | 299(303.1) | 919.7 | 341(341) | 4.75 | – | > 1000 | 448(462.2) | 966.87 |
| Syn_25 | **350(352.4)** | 539.08 | **357(358.6)** | 89.48 | 393(395) | 993.33 | 404(404) | 7.55 | – | > 1000 | 566(589.9) | 972.05 |
| Syn_26 | **160(161.9)** | 685.26 | **163(164.7)** | 78.1 | 167(169.5) | 773.54 | 207(207) | 2.98 | – | > 1000 | 216(220.1) | 871.81 |
| Syn_27 | **180(180)** | 5.33 | **180(180)** | 5.33 | **180(180)** | 45.08 | 204(204) | 2 | – | > 1000 | 194(201.6) | 579.78 |
| Syn_28 | **367(369.9)** | 756.4 | **379(382.5)** | 96.4 | 503(506.5) | 989.24 | 420(420) | 20.25 | – | > 1000 | – | > 1000 |
| Syn_29 | **125(125)** | 39.91 | **125(125)** | 39.91 | **125**(125.4) | 708.87 | 154(154) | 4.67 | – | > 1000 | 186(192) | 920.3 |
| Syn_30 | **66(66.9)** | 418.63 | **68(68.3)** | 53.39 | 69(69.7) | 432.07 | 100(100) | 1.25 | – | > 1000 | 82(88.8) | 455.48 |

**Table 8: Comparing *FastCA* against state-of-the-art competitors for 4-way CCAG. The running time is measured in CPU second.**

| Instance | *FastCA (1000s)* | | *TCA (1000s)* | | *ACTS (1000s)* | | *CASA (1000s)* | |
|---|---|---|---|---|---|---|---|---|
| | min (avg) | time | min (avg) | time | min | time | min (avg) | time |
| apache | – | > 1000 | – | > 1000 | – | > 1000 | – | > 1000 |
| bugzilla | **166(166.7)** | 670.13 | 170(170.9) | 834.17 | 242(242) | 3.8 | 271(278.5) | 910.57 |
| gcc | – | > 1000 | – | > 1000 | – | > 1000 | – | > 1000 |
| spins | **308(308)** | 10.77 | 311(317.1) | 428.88 | 393(393) | 0.44 | 360(366.9) | 781.91 |
| spinv | **1105(1110.7)** | 878.74 | 1634(1653.2) | 979.58 | 1631(1631) | 26.37 | – | > 1000 |
| tcas | **1200(1200)** | 6.26 | **1200(1200)** | 32.55 | 1435(1435) | 0.43 | 1228(1244) | 820.78 |
| Banking1 | 139(**139**) | 5.36 | 139(**139**) | < 0.01 | 139(**139**) | 0.9 | 139(142.3) | 0.03 |
| Banking2 | **71(71)** | 3.45 | **71(71)** | 6.97 | 96(96) | 0.35 | 74(77.4) | 31.57 |
| CommProt. | **83(83)** | 8.53 | **83(83)** | 2.92 | 97(97) | 1.28 | 84(85.1) | 2.45 |
| Concurrency | 8(8) | **<0.01** | 8(8) | **<0.01** | 8(8) | 0.3 | 8(8) | **<0.01** |
| Healthcare1 | **300(300)** | 1.93 | **300(300)** | 1.42 | 341(341) | 0.43 | 301(303.4) | 6.18 |
| Healthcare2 | **166(168.1)** | 733.72 | 172(173.4) | 456.59 | 220(220) | 0.65 | 184(187.4) | 123.55 |
| Healthcare3 | **737(741.2)** | 659.84 | 766(770.4) | 916.78 | 1004(1004) | 2.23 | 1147(1161.3) | 957.1 |
| Healthcare4 | **1332(1341)** | 775.18 | 1728(1740.5) | 997.19 | 1644(1644) | 5.93 | 2557(2598.5) | 956.8 |
| Insurance | **75361(75361)** | 159.06 | 76234(76270.9) | 998.19 | 75764(75764) | 2.35 | 972594(1.06232e+06) | 968.31 |
| NetworkMg. | **5610(5610)** | 336.54 | **5610(5610)** | 500.86 | 6267(6267) | 0.61 | 5944(5974.9) | 970.08 |
| Proc.Comm1 | **487(490.4)** | 486.82 | 491(495) | 577.39 | 670(670) | 0.52 | 574(581.9) | 915.21 |
| Proc.Comm2 | **584(585.6)** | 405.9 | 591(593.4) | 867.96 | 744(744) | 2.69 | 840(860.5) | 941.5 |
| Services | **6404(6406.9)** | 875.72 | 6418(6422.2) | 928.33 | 6855(6855) | 7.92 | 7081(7227.3) | 943.63 |
| Storage1 | 25(25) | 1.84 | 25(25) | **<0.01** | 25(25) | 0.7 | 25(25) | 0.02 |
| Storage2 | **162(162)** | 17.68 | **162(162)** | 0.15 | 195(195) | 0.02 | **162**(163.6) | 0.33 |
| Storage3 | **570(570)** | 63.69 | **570(570)** | 304.76 | 752(752) | 0.84 | 1085(1085) | 35.52 |
| Storage4 | **5506(5508.2)** | 927 | 6625(6695.5) | 999.14 | 6636(6636) | 2.15 | 9278(9370.4) | 947.33 |
| Storage5 | **11004(11020.7)** | 977.27 | 14065(14086.4) | 993.27 | 13292(13292) | 17.63 | – | > 1000 |
| SystemMg. | **135(135)** | 2.64 | **135(135)** | 2 | 152(152) | 0.36 | 136(140) | 6.25 |
| Telecom | **360(360)** | 2.3 | **360(360)** | 2.62 | 392(392) | 0.38 | 365(365.4) | 19.96 |
| Syn_1 | **1680(1680)** | 634.13 | – | > 1000 | **1680(1680)** | 600.5 | – | > 1000 |
| Syn_2 | **705(712.4)** | 984.55 | – | > 1000 | 873(873) | 236.5 | – | > 1000 |
| Syn_3 | **156(156)** | 229.53 | 157(157) | 445.77 | 212(212) | 0.67 | 179(197.7) | 306.31 |
| Syn_4 | **295(298.5)** | 785.42 | 338(345) | 990.5 | 374(374) | 7.32 | 809(809) | 812.07 |
| Syn_5 | – | > 1000 | – | > 1000 | – | > 1000 | – | > 1000 |
| Syn_6 | **384(384.2)** | 755.41 | 508(514.5) | 978.28 | 491(491) | 48.39 | – | > 1000 |
| Syn_7 | **74(74)** | 285.79 | 75(75) | 327.08 | 93(93) | 0.72 | 78(79.5) | 586.87 |
| Syn_8 | – | > 1000 | – | > 1000 | – | > 1000 | – | > 1000 |
| Syn_9 | **200(200.5)** | 709.24 | 203(207.9) | 985.32 | 268(268) | 7.39 | 4440(4440) | 737.49 |
| Syn_10 | – | > 1000 | – | > 1000 | – | > 1000 | – | > 1000 |
| Syn_11 | **1885(1885)** | 721.6 | – | > 1000 | **1885(1885)** | 716.36 | – | > 1000 |
| Syn_12 | – | > 1000 | – | > 1000 | – | > 1000 | – | > 1000 |
| Syn_13 | – | > 1000 | – | > 1000 | – | > 1000 | – | > 1000 |
| Syn_14 | **1033(1044.4)** | 993.43 | – | > 1000 | 1163(1163) | 379.67 | – | > 1000 |
| Syn_15 | **615(619.6)** | 959.87 | 849(863.7) | 990.73 | 770(770) | 14.09 | 1761(2051.5) | 907.69 |
| Syn_16 | **360(364.3)** | 942.45 | 536(542) | 965.56 | 453(453) | 112.38 | – | > 1000 |
| Syn_17 | – | > 1000 | – | > 1000 | – | > 1000 | – | > 1000 |
| Syn_18 | – | > 1000 | – | > 1000 | – | > 1000 | – | > 1000 |
| Syn_19 | – | > 1000 | – | > 1000 | – | > 1000 | – | > 1000 |
| Syn_20 | – | > 1000 | – | > 1000 | – | > 1000 | – | > 1000 |
| Syn_21 | **893(897.4)** | 987.81 | 1294(1303.5) | 946.2 | 1070(1070) | 169.26 | – | > 1000 |
| Syn_22 | **542(545.2)** | 927.38 | 790(799.9) | 961.45 | 664(664) | 55.22 | – | > 1000 |
| Syn_23 | **103(103.1)** | 294.27 | **103**(103.9) | 371.91 | 140(140) | 0.67 | 113(122.9) | 201.58 |
| Syn_24 | – | > 1000 | – | > 1000 | – | > 1000 | – | > 1000 |
| Syn_25 | – | > 1000 | – | > 1000 | – | > 1000 | – | > 1000 |
| Syn_26 | **921(933.5)** | 995.62 | – | > 1000 | 1111(1111) | 336.01 | – | > 1000 |
| Syn_27 | **776(784.1)** | 935.86 | 1142(1157.2) | 977.7 | 1004(1004) | 24.07 | 4599(4619.14) | 930.13 |
| Syn_28 | – | > 1000 | – | > 1000 | – | > 1000 | – | > 1000 |
| Syn_29 | – | > 1000 | – | > 1000 | – | > 1000 | – | > 1000 |
| Syn_30 | **274(275.6)** | 914.62 | 393(400) | 981.74 | 386(386) | 40.32 | – | > 1000 |

**Table 9: Comparing *FastCA* against its alternative versions for 3-way CCAG on real-world benchmark. The running time is measured in CPU second. The cutoff time is set to 1000s**

| Instance | *FastCA* | | *FastCA-* | | *FastCAp* | | *FastCAp-* | |
|---|---|---|---|---|---|---|---|---|
| | min (avg) | time | min (avg) | time | min | time | min (avg) | time |
| apache | **133**(**134.7**) | 716.77 | 135(137.2) | 600.12 | 149(150.6) | 869.11 | 141(143.5) | 750.65 |
| bugzilla | 48(**48**) | 17.35 | 48(**48**) | 3.51 | 48(48.2) | 141.69 | 48(**48**) | 20.8 |
| gcc | **75**(**76.8**) | 561.74 | 77(78.4) | 565.27 | 86(88.7) | 761.75 | 80(81.6) | 565.17 |
| spins | 80(80) | 1.17 | 80(80) | **0.85** | 80(80) | 3 | 80(80) | 1.1 |
| spinv | **195**(**196**) | 415.45 | 196(196.4) | 485.43 | 199(200.2) | 578.34 | 197(197.7) | 582.34 |
| tcas | 400(400) | **0.47** | 400(400) | 0.83 | 400(400) | 0.79 | 400(400) | 0.89 |
| Banking1 | 45(45) | 4.1 | 45(45) | 4.1 | 45(45) | 4.39 | 45(45) | **4.09** |
| Banking2 | 30(30) | 0.66 | 30(30) | **0.42** | 30(30) | 2.41 | 30(30) | 0.68 |
| CommProtocol | 41(41) | 16.68 | 41(41) | **7.97** | 41(41) | 32.01 | 41(41) | 8.53 |
| Concurrency | 8(8) | **0.31** | 8(8) | 0.4 | 8(8) | 0.82 | 8(8) | 0.73 |
| Healthcare1 | 96(96) | 0.8 | 96(96) | 0.77 | 96(96) | **0.7** | 96(96) | **0.7** |
| Healthcare2 | **50**(**50.9**) | 225.47 | 51(51.8) | 55.03 | **50**(51.4) | 143.98 | 51(51.8) | 119.55 |
| Healthcare3 | **151**(**151.5**) | 325.85 | 152(152.1) | 383.44 | 152(153.6) | 400.97 | 152(152.8) | 365.42 |
| Healthcare4 | **238**(**239**) | 417.3 | **238**(239.4) | 323.33 | 241(242.5) | 669.05 | 239(241) | 516.67 |
| Insurance | 6851(6851) | **1.74** | 6851(6851) | 1.81 | 6851(6851) | 2.65 | 6851(6851) | 2.89 |
| NetworkMgmt | 1100(1100) | **1.14** | 1100(1100) | 1.41 | 1100(1100) | 1.38 | 1100(1100) | 1.52 |
| ProcessorComm1 | **104**(**104.8**) | 160.59 | 105(105.3) | 172.91 | 105(105.3) | 277.59 | 105(105.4) | 243.69 |
| ProcessorComm2 | 125(**125.6**) | 189.36 | 125(125.8) | 405.52 | 125(126.6) | 399.12 | 125(126.5) | 307.75 |
| Services | **813**(**815.2**) | 685.53 | **813**(815.5) | 663.97 | 818(821.6) | 857.58 | 816(817.8) | 601.2 |
| Storage1 | 25(25) | 2.05 | 25(25) | 2.08 | 25(25) | 2.15 | 25(25) | **1.48** |
| Storage2 | 54(54) | **0.09** | 54(54) | **0.09** | 54(54) | 0.2 | 54(54) | **0.09** |
| Storage3 | 222(222) | 3.43 | 222(222) | **3.32** | 222(222) | 5.94 | 222(222) | 5.58 |
| Storage4 | 910(910) | 3.62 | 910(910) | **3.36** | 910(910) | 17.53 | 910(910) | 13.78 |
| Storage5 | **1705**(**1706.9**) | 445.17 | 1706(1708) | 452.46 | 1707(1710) | 550.44 | 1707(1710.6) | 501.23 |
| SystemMgmt | 45(45) | 1.65 | 45(45) | **1.2** | 45(45) | 3.77 | 45(45) | 1.53 |
| Telecom | 120(120) | **0.57** | 120(120) | 0.66 | 120(120) | 1.11 | 120(120) | 0.87 |