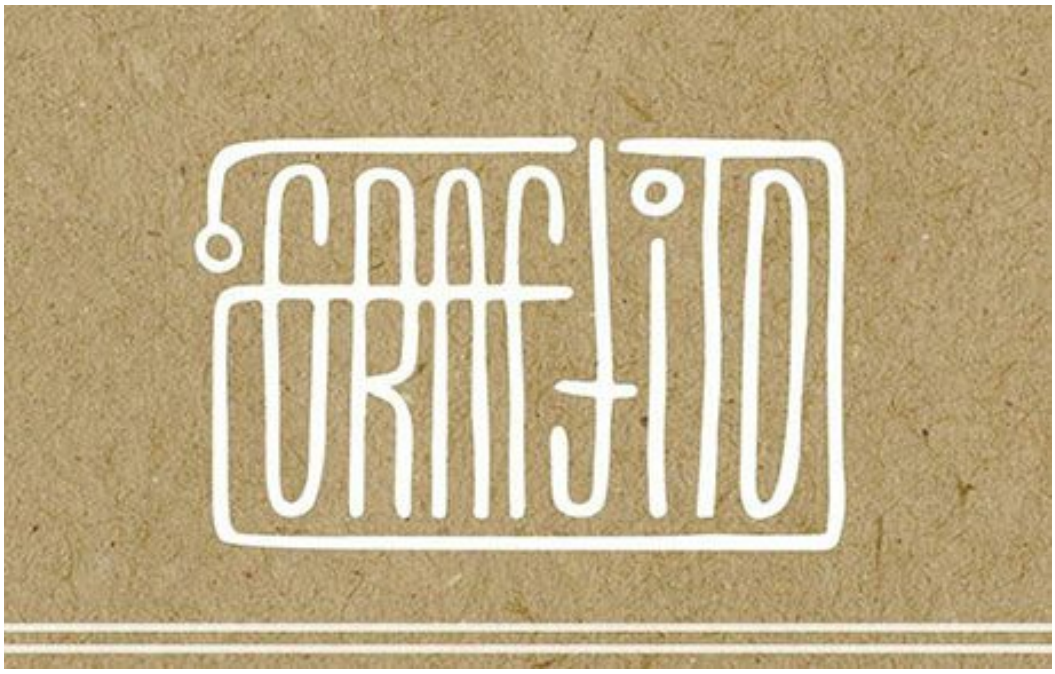
GRAPHITO SOFTWARE



OUTPUT PRODUCED BY

GROUP NO : 5

Indian Institute of Technology Kharagpur

Open Soft Problem Statement

February 23, 2016

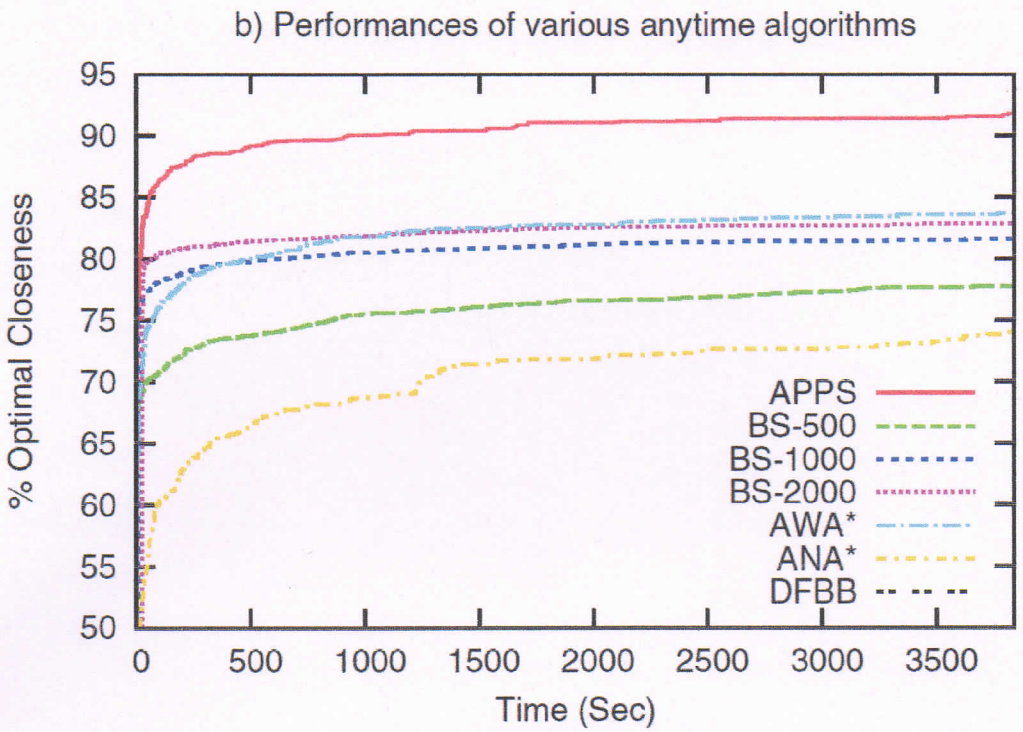
Plots to Tables

The input is a set of (multiple) scanned pdf pages, each containing (one or more) figures which are two-dimensional plots of experimental results. A scanned page can have a single or multiple plots which may or may not be embedded in text. Each plot has the x and y axis with their labels and unit measurements marked in the plot (linear scale). Inside each figure are one or more plots, each with a different colour depicting a certain plotted entity (E_i) and their labels given separately within the plot as a caption. (The example enclosed shows such an input set.)

You are required to read a set of scanned pages as input where each page has one or more plots embedded in text and convert them to a set of two-dimensional tables, one table per plot, where each row of the table has the following values - the x-axis value, y-axis value and values for each E_i or a dash (-) in case there is no value for that E_i. Each Table should have the first row as the name labels for the x-axis, y-axis and various E_i values. It should cover x and y axis values from the minimum to maximum range with one tenth of the minimum marked unit in the plot as granularity. The Table as a whole will have a caption as per the caption of the figure.

The output will be a set of pdf pages which contain the name of the participant as the first page followed by a sequence of results having the first input page followed by the set of tables corresponding to the figures in that page (one table per page) followed by the next input page and the tables of that page, etc.

An example set of input pages is enclosed.


b) Performances of various anytime algorithms
% Optimal Closeness
95
90
85
80
75
70
65
60
55
50
0
500
1000
1500
2000
2500
3000
3500
Time (Sec)
APPS
BS-500
BS-1000
BS-2000
AWA*
ANA*
DFBB

GOO i OOO iSOO ZOOO 25 OptiBACOSOOS Time (Sec)								
	114.0 138.0 158.0	82.0 53.0 232.0	181.0 124.0 123.0	218.0 206.0 172.0	149.0 203.0 186.0	157.0 70.0 160.0	173.0 123.0 125.0	119.0 163.0 110.0
0.0	66.2020905923345	43.98954703832753	96.51567944250871	9.843205574912892	21.341463414634145	99.21602787456446	47.12543554006969	66.55052264808363
1.9704433497536946	10.278745644599303	20.29616724738676	37.02090592334495	42.1602787456446	53.745644599303134	32.055749128919864	-	54.70383275261324
3.9408866995073892	99.82578397212544	16.637630662020907	0.08710801393728224	40.41811846689895	51.13240418118467	31.70731707317073	-	51.829268292682926
5.911330049261084	70.47038327526133	15.679442508710801	-	36.933797909407666	49.041811846689896	31.62020905923345	-	49.91289198606272
7.8817733990147785	68.03135888501743	14.111498257839722	-	34.84320557491289	48.606271777003485	14.547038327526133	-	48.86759581881533
9.852216748768473	99.73867595818815	14.111498257839722	-	-	47.12543554006969	30.574912891986063	-	47.90940766550523
11.822660098522167	99.73867595818815	13.414634146341463	-	33.53658536585366	46.68989547038328	13.850174216027874	-	47.64808362369338
13.793103448275861	99.73867595818815	12.543554006968641	-	32.57839721254356	46.51567944250871	30.226480836236934	-	47.12543554006969
15.763546798029557	99.73867595818815	11.759581881533101	-	32.57839721254356	45.90592334494774	29.965156794425088	-	46.68989547038328
17.733990147783253	60.801393728223	11.67247386759582	-	31.358885017421603	45.29616724738676	29.878048780487806	32.40418118466899	46.0801393728223
19.704433497536947	59.75609756097561	11.498257839721255	-	33.10104529616725	44.599303135888505	11.846689895470384	-	45.383275261324044
21.67487684729064	59.84320557491289	11.236933797909408	-	30.139372822299652	43.90243902439025	29.355400696864113	29.529616724738677	44.86062717770035
23.645320197044335	99.73867595818815	10.975609756097562	-	28.9198606271777	43.1184668989547	11.585365853658537	28.658536585365855	43.98954703832753
25.61576354679803	99.65156794425087	10.627177700348431	-	29.181184668989548	42.77003484320557	10.975609756097562	-	43.641114982578394
27.586206896551722	57.491289198606275	10.714285714285714	-	29.006968641114984	42.508710801393725	99.91289198606272	28.571428571428573	43.20557491289198
29.55665024630542	99.73867595818815	10.452961672473867	28.39721254355401	32.055749128919864	57.57839721254356	99.91289198606272	31.18466898954704	-
31.527093596059114	99.65156794425087	9.930313588850174	-	28.048780487804876	42.24738675958188	99.91289198606272	-	43.1184668989547
33.49753694581281	99.73867595818815	9.843205574912892	-	27.4390243902439	42.42160278745644	99.91289198606272	-	42.857142857142854
35.467980295566505	99.65156794425087	9.930313588850174	-	27.264808362369337	41.724738675958186	28.571428571428573	99.91289198606272	42.59581881533101
37.4384236453202	52.09059233449477	9.843205574912892	-	27.264808362369337	41.55052264808362	28.222996515679444	27.961672473867594	42.508710801393725
39.40886699507389	99.65156794425087	9.843205574912892	27.78745644599303	27.264808362369337	41.289198606271775	27.961672473867594	30.83623693379791	41.98606271777003
41.37931034482759	51.91637630662021	9.40766550522648	-	27.35191637630662	40.940766550522646	27.874564459930312	27.700348432055748	41.89895470383275
43.34975369458128	51.742160278745644	8.97212543554007	30.574912891986063	99.82578397212544	40.940766550522646	28.135888501742162	30.48780487804878	41.55052264808362
45.320197044334975	50.78397212543554	8.18815331010453	-	27.090592334494772	40.853658536585364	8.623693379790941	-	41.46341463414634
47.29064039408867	99.56445993031359	8.362369337979095	-	26.56794425087108	40.6794425087108	27.264808362369337	27.090592334494772	41.37630662020906
49.26108374384236	99.65156794425087	8.362369337979095	-	26.742160278745644	40.24390243902439	27.78745644599303	99.82578397212544	40.940766550522646
51.23152709359606	99.56445993031359	8.362369337979095	-	26.742160278745644	40.24390243902439	27.613240418118465	99.91289198606272	40.940766550522646
53.20197044334975	99.65156794425087	8.275261324041812	-	26.56794425087108	99.56445993031359	99.91289198606272	-	-
55.172413793103445	50.87108013937282	8.275261324041812	-	26.480836236933797	40.15679442508711	27.177700348432055	-	40.853658536585364
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59.11330049261084	99.56445993031359	8.275261324041812	-	26.306620209059233	40.15679442508711	27.526132404181183	-	40.853658536585364
61.083743842364534	99.65156794425087	7.839721254355401	-	25.871080139372822	39.89547038327526	8.449477351916377	30.139372822299652	40.6794425087108
63.05418719211823	99.56445993031359	8.013937282229966	-	25.78397212543554	39.721254355400696	27.35191637630662	-	40.41811846689895
65.02463054187191	96.42857142857143	8.013937282229966	-	-	39.45993031358885	27.35191637630662	3.048780487804878	40.41811846689895
66.99507389162562	49.73867595818815	7.7526132404181185	-	26.13240418118467	99.91289198606272	27.090592334494772	27.35191637630662	-
68.96551724137932	66.98606271777004	7.578397212543554	67.59581881533101	25.34843205574913	39.285714285714285	26.829268292682926	-	40.15679442508711
70.93596059113301	60.88850174216028	7.578397212543554	77.26480836236934	67.6829268292683	39.11149825783972	68.72822299651568	77.17770034843205	39.80836236933798
72.9064039408867	60.97560975609756	7.7526132404181185	-	25.871080139372822	57.75261324041812	27.264808362369337	75.9581881533101	39.63414634146341
74.8768472906404	99.56445993031359	80.31358885017421	70.99303135888502	75.87108013937282	38.850174216027874	27.264808362369337	63.937282229965156	39.63414634146341
76.84729064039409	73.08362369337979	7.665505226480836	56.96864111498258	25.871080139372822	38.76306620209059	27.00348432055749	73.5191637630662	39.45993031358885
78.81773399014779	64.98257839721255	7.578397212543554	-	25.696864111498257	38.58885017421603	55.57491289198606	67.59581881533101	39.285714285714285
80.78817733990148	61.062717770034844	7.229965156794425	67.59581881533101	25.0	64.80836236933798	27.090592334494772	61.41114982578397	-
82.75862068965517	99.91289198606272	7.491289198606272	-	-	37.97909407665505	27.35191637630662	-	38.850174216027874
84.72906403940887	99.56445993031359	7.578397212543554	93.46689895470384	24.912891986062718	63.066202090592334	75.60975609756098	-	38.58885017421603
86.69950738916256	99.56445993031359	57.491289198606275	-	25.087108013937282	63.153310104529616	99.91289198606272	99.82578397212544	63.76306620209059
88.66995073891626	86.93379790940766	7.578397212543554	93.72822299651568	81.27177700348432	63.153310104529616	75.60975609756098	99.73867595818815	38.58885017421603
90.64039408866995	48.78048780487805	7.665505226480836	-	24.912891986062718	63.2404181184669	75.34843205574913	99.91289198606272	38.501742160278745
92.61083743842364	99.4773519163763	7.578397212543554	93.81533101045297	99.73867595818815	63.066202090592334	99.91289198606272	93.6411149825784	38.501742160278745
94.58128078817734	47.47386759581882	57.57839721254356	-	25.174216027874564	63.32752613240418	75.69686411149826	93.81533101045297	63.76306620209059
96.55172413793103	99.4773519163763	7.142857142857143	-	25.0	37.54355400696864	7.491289198606272	99.82578397212544	38.32752613240418
98.52216748768473	54.79094076655052	6.968641114982578	10.888501742160278	24.65156794425087	37.80487804878049	43.90243902439025	10.975609756097562	38.32752613240418

Figure: b) Performances of various anytime algorithms

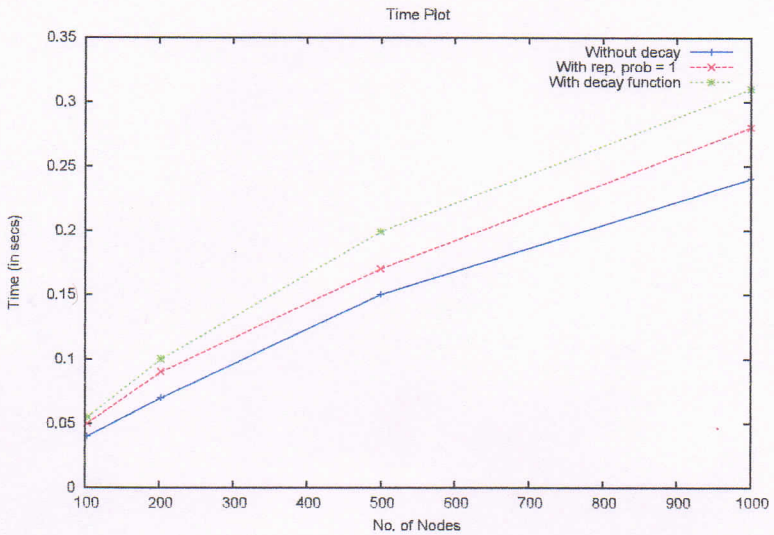


Figure 3.3: Variation of metric computation time (in sec) with size of attack graphs. Memoryless, partial memory and full memory of attacker for repeated vulnerabilities are considered. Time is reported in seconds.

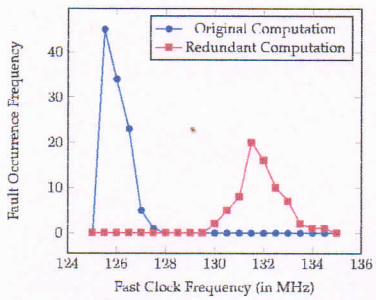
Workstation (8 GB memory). It can be seen that the the growth of computational time is sub-exponential. The computation time is highest for the case of partial memory attacker scenario.

3.5 Conclusion

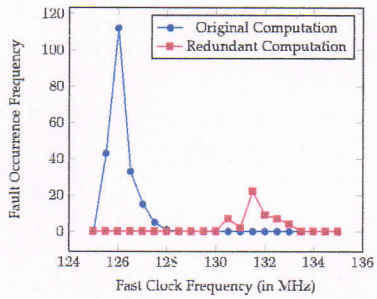
Security analysis is a challenging problem due to inherent complexities of attack modalities, scale and computational cost. We present a structured framework for probabilistic security metric computation using an multiplicative idempotency operation that can handle repeated vulnerabilities in an attack path. Proof of correctness and complexity analysis of security metric computation are provided. The metric is then extended to model the scenario where attackers have (i) full memory of previous exploits, (ii) partial memory of repeated vulnerabilities as characterized by a decay function, and (iii) no memory of past exploits. The metrics are then used for computing vulnerabilities of large attack graphs having cycles and repeated vulnerabilities. Scalability of the propose method with increasing network size is studied.

Nov of Nodes	Time On secs)					
	186.0 224.0 218.0	175.0 162.0 214.0	178.0 122.0 93.0	215.0 152.0 154.0	126.0 158.0 127.0	99.0 100.0 96.0
100.0	0.1983940042826553	0.34828693790149895	0.3591541755888651	0.3580299785867238	0.3460385438972163	0.0990899357601713
117.58321273516643	0.33554603854389725	0.341541755888651	0.35315845824411135	-	0.33667023554603853	-
135.16642547033285	0.3988758029978587	0.3340471092077088	0.34828693790149895	-	0.3288008565310493	-
152.74963820549928	0.3988758029978587	0.3273019271948608	0.34304068522483944	-	-	0.34229122055674516
170.3328509406657	0.39850107066381163	0.3213062098501071	0.338169164882227	-	-	-
187.9160636758321	0.39850107066381163	0.31418629550321203	0.33217344753747324	-	-	-
205.49927641099856	0.3988758029978587	-	0.3284261241970021	-	-	-
223.08248914616496	0.29132762312633836	0.3021948608137045	0.3235546038543897	0.3220556745182013	-	-
240.66570188133142	-	0.2980728051391863	0.31905781584582443	-	0.28533190578158457	0.28570663811563174
258.2489146164978	0.27933618843683083	0.29395074946466815	0.3138115631691649	-	0.27971092077087795	-
275.8321273516642	-	-	0.30894004282655246	-	-	0.3096895074946467
293.41534008683067	-	0.3988758029978587	0.30369379014989295	-	-	-
310.9985528219971	0.26209850107066385	0.27858672376873667	0.29919700214132766	-	-	-
328.5817655571635	0.25572805139186294	0.2740899357601713	0.2947002141327623	-	-	-
346.1649782923299	0.2493576017130621	0.3988758029978587	0.2898286937901499	-	-	-
363.7481910274964	-	0.3988758029978587	0.28570663811563174	-	-	-
381.33140376266283	-	0.25947537473233406	0.28046038543897217	0.27971092077087795	-	-
398.91461649782923	-	0.2549785867237688	0.27521413276231266	-	-	-
416.4978292329957	0.22612419700214137	0.25085653104925054	0.2707173447537473	-	0.22612419700214137	-
434.0810419681621	0.22012847965738758	0.24561027837259103	0.2658458244111349	-	0.2212526766595289	-
451.6642547033285	-	0.24036402569593152	0.2609743040685225	-	-	-
469.24746743849494	-	0.23586723768736617	0.2572269807280514	0.2561027837259101	-	-
486.83068017366134	0.20364025695931476	0.231745182012848	0.252355460385439	-	-	-
504.4138929088278	0.1983940042826553	0.3988758029978587	0.24823340471092076	0.24710920770877948	0.19876873661670236	0.19876873661670236
521.9971056439942	-	0.22275160599571736	0.2444860813704497	-	-	-
539.5803183791606	0.19052462526766595	0.2190042826552463	0.24073875802997857	-	-	-
557.163531114327	0.18602783725910066	0.21525695931477518	0.23886509635974307	0.23774089935760173	-	-
574.7467438494934	0.3992505353319058	0.21188436830835122	0.23474304068522484	-	-	-
592.3299565846598	0.17853319057815847	0.20851177730192721	0.23249464668094222	-	0.17890792291220559	0.1796573875802998
609.9131693198264	-	0.3988758029978587	0.228372591006424	-	-	-
627.4963820549928	0.1714132762312634	0.2002676659528908	0.22537473233404715	-	-	-
645.0795947901591	0.1669164882226981	0.19614561027837257	0.22237687366167025	-	-	-
662.6628075253257	0.3992505353319058	0.19314775160599573	0.21975374732334046	0.2190042826552463	-	-
680.2460202604921	0.1590471092077088	0.18902569593147756	0.2160064239828694	-	0.16017130620985012	-
697.8292329956585	-	0.18527837259100643	0.2126338329764454	0.05337259100642398	-	-
715.4124457308249	0.3992505353319058	-	0.20963597430406855	-	-	-
732.9956584659914	0.1478051391862955	0.1766595289079229	0.20626338329764454	0.08485010706638116	-	-
750.5788712011578	0.08035331905781584	0.17328693790149893	0.20438972162740904	0.08410064239828693	-	-
768.1620839363242	0.06761241970021414	0.16916488222698073	0.2002676659528908	0.07135974304068524	0.06798715203426124	0.06798715203426124
785.7452966714906	0.05562098501070664	0.16654175588865097	0.05674518201284797	0.07248394004282656	-	-
803.328509406657	0.057119914346895076	0.16204496788008566	0.19464668094218418	0.0781049250535332	0.07135974304068524	0.07098501070663812
820.9117221418235	0.12869379014989293	0.08372591006423984	0.08859743040685225	0.05861884368308352	-	-
838.4949348769899	0.06911134903640258	0.15380085653104925	0.06349036402569594	0.1875267665952891	-	-
856.0781476121563	0.06274089935760171	0.1504282655246253	0.18527837259100643	0.07135974304068524	-	-
873.6613603473227	0.08447537473233405	0.14668094218415417	0.0702355460385439	0.0822269807280514	-	-
891.2445730824892	0.06836188436830835	0.14218415417558888	0.1792826552462527	0.06086723768736617	-	0.06161670235546039
908.8277858176556	0.10920770877944326	0.1395610278372591	0.17553533190578158	-	-	-
926.410998552822	0.3992505353319058	0.07098501070663812	0.05899357601713062	-	0.08335117773019272	-
943.9942112879884	0.10096359743040687	0.07098501070663812	0.059368308351177734	-	0.08485010706638116	0.08559957173447538
961.5774240231549	0.08372591006423984	0.1271948608137045	0.06011777301927195	-	-	-
979.1606367583213	0.3992505353319058	0.12344753747323342	0.16279443254817988	-	-	-
996.7438494934877	0.14855460385438973	0.12007494646680943	0.1594218415417559	0.2504817987152035	0.09084582441113491	0.24898286937901504

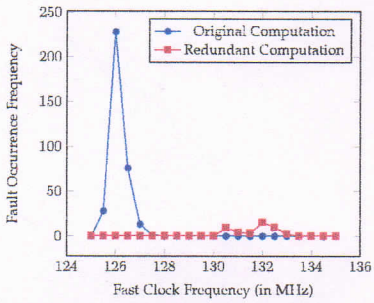
Figure: Time Plot



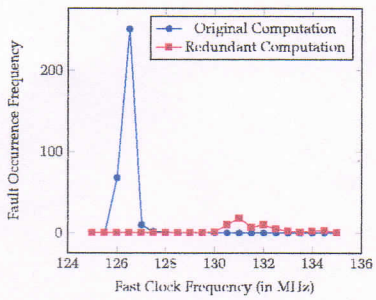
(a) Fault Space Transformation : SBU



(b) Fault Space Transformation : SBDBU

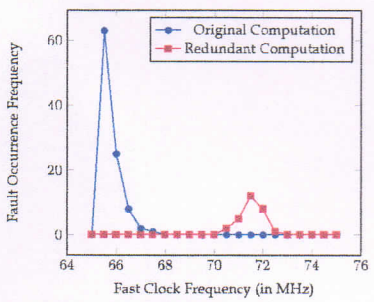


(c) Fault Space Transformation : SBTBU

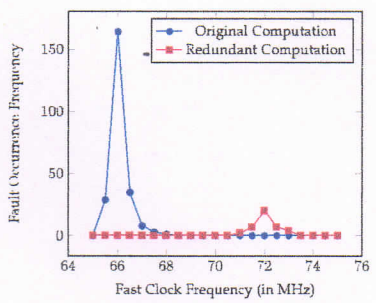


(d) Fault Space Transformation : SBQBU

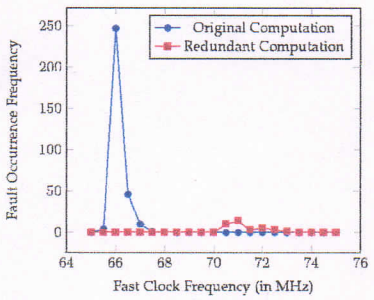
Fig. 9: Effect of Fault Space Transformation on the Time Redundancy Countermeasure



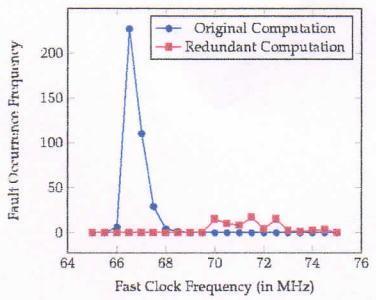
(a) Fault Space Transformation : SBU



(b) Fault Space Transformation : SBDBU



(c) Fault Space Transformation : SBTBU



(d) Fault Space Transformation : SBQBU

Fig. 10: Effect of Fault Space Transformation on the Hardware Redundancy Countermeasure

M BS SS TU TZ M TB Fast Clock Frequency (in MHz) (d) Fourth Space Transformation z SBQBU				
	176.0 202.0 248.0	228.0 177.0 161.0	135.0 102.0 199.0	124.0 64.0 118.0
0.0	284.81404958677683	-	289.1528925619835	-
1.9784172661870503	284.09090909090907	-	286.2603305785124	-
3.9568345323741005	286.2603305785124	-	289.87603305785126	292.04545454545456
5.9352517985611515	284.81404958677683	282.64462809917353	285.53719008264466	283.3677685950413
7.913669064748201	283.3677685950413	274.6900826446281	289.87603305785126	281.198347107438
9.892086330935252	284.81404958677683	169.11157024793388	286.2603305785124	-
11.870503597122303	279.75206611570246	-21.074380165289256	291.3223140495868	-
13.848920863309353	282.64462809917353	-21.797520661157026	290.599173553719	-
15.827338129496402	281.198347107438	77.27272727272727	289.1528925619835	291.3223140495868
17.805755395683452	284.81404958677683	132.95454545454547	290.599173553719	-
19.784172661870503	-	197.31404958677686	284.81404958677683	286.2603305785124
21.762589928057555	280.47520661157023	234.91735537190084	291.3223140495868	-
23.741007194244606	284.81404958677683	259.504132231405	286.2603305785124	-
25.719424460431654	286.2603305785124	279.75206611570246	292.04545454545456	281.198347107438
27.697841726618705	284.81404958677683	278.3057851239669	288.4297520661157	281.198347107438
29.676258992805757	282.64462809917353	-49.27685950413223	289.87603305785126	291.3223140495868
31.654676258992804	279.75206611570246	-49.27685950413223	291.3223140495868	-
33.63309352517986	-	-49.27685950413223	284.81404958677683	286.2603305785124
35.611510791366904	280.47520661157023	-49.27685950413223	291.3223140495868	292.04545454545456
37.589928057553955	284.81404958677683	-49.27685950413223	285.53719008264466	286.2603305785124
39.568345323741006	280.47520661157023	-49.27685950413223	289.87603305785126	-
41.54676258992806	278.3057851239669	-49.27685950413223	283.3677685950413	286.2603305785124
43.52517985611511	259.504132231405	286.2603305785124	263.1198347107438	284.09090909090907
45.50359712230216	265.2892561983471	289.1528925619835	270.3512396694215	271.797520661157
47.48201438848921	268.1818181818182	286.2603305785124	268.1818181818182	-
49.460431654676256	266.73553719008265	283.3677685950413	276.8595041322314	-
51.43884892086331	272.5206611570248	286.2603305785124	273.9669421487603	-
53.41726618705036	269.6280991735537	284.81404958677683	279.75206611570246	280.47520661157023
55.39568345323741	270.3512396694215	286.2603305785124	276.1363636363636	-
57.37410071942446	265.2892561983471	285.53719008264466	268.1818181818182	-
59.35251798561151	260.9504132231405	286.9834710743802	268.1818181818182	-
61.330935251798564	-	285.53719008264466	274.6900826446281	284.81404958677683
63.30935251798561	275.41322314049586	288.4297520661157	284.81404958677683	285.53719008264466
65.28776978417267	273.24380165289256	286.2603305785124	273.9669421487603	-
67.26618705035972	264.56611570247935	284.81404958677683	270.3512396694215	-
69.24460431654676	268.90495867768595	288.4297520661157	271.07438016528926	-
71.22302158273381	282.64462809917353	289.87603305785126	276.8595041322314	287.70661157024796
73.20143884892086	280.47520661157023	-49.27685950413223	284.81404958677683	287.70661157024796
75.17985611510791	284.09090909090907	-	284.81404958677683	285.53719008264466
77.15827338129496	286.9834710743802	292.04545454545456	288.4297520661157	289.87603305785126
79.13669064748201	283.3677685950413	285.53719008264466	284.81404958677683	284.81404958677683
81.11510791366906	277.58264462809916	289.1528925619835	286.2603305785124	288.4297520661157
83.09352517985612	281.198347107438	286.2603305785124	283.3677685950413	284.09090909090907
85.07194244604317	275.41322314049586	288.4297520661157	284.09090909090907	286.9834710743802
87.05035971223022	276.1363636363636	290.599173553719	284.81404958677683	286.9834710743802
89.02877697841727	284.09090909090907	-49.27685950413223	284.81404958677683	285.53719008264466
91.00719424460432	280.47520661157023	-49.27685950413223	290.599173553719	292.04545454545456
92.98561151079137	-	-49.27685950413223	-	-
94.96402877697842	-	-	-	-
96.94244604316546	-	-	-	-
98.92086330935251	-	-49.27685950413223	15.805785123966942	16.52892561983471

þÿFigure: | Q)û Space Transformation : SBDBU

Past Clock Frequency (in MHz)	Fault Occurrence Frequency		
	197.0 174.0 152.0	169.0 161.0 255.0	127.0 85.0 120.0
64.0	-	160.1195219123506	160.35856573705178
64.23880597014926	-	-	-
64.4776119402985	-	-	-
64.71641791044776	-	-	-
64.95522388059702	-	179.4820717131474	182.58964143426294
65.19402985074626	179.9601593625498	180.43824701195217	179.4820717131474
65.43283582089552	178.52589641434264	179.9601593625498	179.003984063745
65.67164179104478	143.38645418326695	180.67729083665338	-
65.91044776119404	91.51394422310757	179.9601593625498	-
66.14925373134328	101.31474103585657	180.199203187251	-
66.38805970149254	146.49402390438246	179.72111553784862	-
66.6268656716418	161.55378486055776	179.9601593625498	-
66.86567164179104	172.54980079681275	181.39442231075697	-
67.1044776119403	178.28685258964146	179.003984063745	-
67.34328358208955	-	179.9601593625498	178.76494023904382
67.58208955223881	-	180.199203187251	-
67.82089552238806	-	179.003984063745	-
68.05970149253731	-	180.199203187251	-
68.29850746268657	-	180.9163346613546	-
68.53731343283582	-	181.15537848605578	182.58964143426294
68.77611940298507	-	180.43824701195217	-
69.01492537313433	-	179.72111553784862	182.58964143426294
69.25373134328358	-	180.43824701195217	-
69.49253731343283	-	179.24302788844622	-
69.73134328358209	-	180.199203187251	-
69.97014925373135	-	179.003984063745	-
70.2089552238806	180.9163346613546	179.003984063745	-
70.44776119402985	180.43824701195217	174.70119521912352	-
70.68656716417911	181.15537848605578	176.61354581673305	-
70.92537313432835	182.35059760956176	174.9402390438247	-
71.16417910447761	181.87250996015936	173.26693227091633	-
71.40298507462687	182.11155378486058	178.28685258964146	180.9163346613546
71.64179104477611	181.15537848605578	177.80876494023903	180.67729083665338
71.88059701492537	181.15537848605578	178.28685258964146	180.199203187251
72.11940298507463	181.15537848605578	178.28685258964146	180.43824701195217
72.35820895522389	180.67729083665338	179.003984063745	180.199203187251
72.59701492537313	182.35059760956176	178.28685258964146	181.15537848605578
72.83582089552239	181.15537848605578	179.9601593625498	180.43824701195217
73.07462686567165	182.82868525896413	180.43824701195217	181.87250996015936
73.31343283582089	-	180.199203187251	-
73.55223880597015	-	179.003984063745	182.82868525896413
73.7910447761194	-	180.199203187251	-
74.02985074626866	-	180.67729083665338	-
74.26865671641791	-	180.43824701195217	180.9163346613546
74.50746268656717	-	179.72111553784862	-
74.74626865671642	-	181.15537848605578	-
74.98507462686567	-	179.003984063745	-
75.22388059701493	-	179.003984063745	-
75.46268656716418	-	-	-
75.70149253731343	-	-	-
75.94029850746269	119.4820717131474	-	-

Figure: (a) Fault Space Transformation : SBU

Si BS SB TO T H TS Fast Clock Frequency (in MHz) (b) Fault Space Transformation z SBDBU					
	210.0 159.0 163.0	220.0 175.0 172.0	185.0 177.0 237.0	76.0 108.0 114.0	198.0 144.0 203.0
0.0	154.37142857142857	807.1714285714286	826.1142857142858	-	836.3142857142857
1.981981981981982	154.37142857142857	721.2	820.2857142857143	-	842.1428571428571
3.963963963963964	154.37142857142857	151.45714285714286	826.1142857142858	-	842.1428571428571
5.945945945945946	152.9142857142857	407.9142857142857	829.0285714285715	-	833.4
7.927927927927928	154.37142857142857	202.45714285714286	827.5714285714286	-	843.6
9.90990990990991	154.37142857142857	402.0857142857143	829.0285714285715	827.5714285714286	833.4
11.891891891891891	-	693.5142857142857	833.4	-	-
13.873873873873874	152.9142857142857	151.45714285714286	829.0285714285715	-	842.1428571428571
15.855855855855856	152.9142857142857	804.2571428571429	829.0285714285715	-	842.1428571428571
17.83783783783784	284.0571428571428	151.45714285714286	834.8571428571429	-	278.2285714285714
19.81981981981982	285.51428571428573	151.45714285714286	827.5714285714286	278.2285714285714	281.1428571428571
21.8018018018018	820.2857142857143	151.45714285714286	836.3142857142857	-	821.7428571428571
23.783783783783782	827.5714285714286	821.7428571428571	830.4857142857143	-	833.4
25.765765765765767	-	151.45714285714286	831.9428571428572	-	843.6
27.74774774774775	-	151.45714285714286	821.7428571428571	-	827.5714285714286
29.72972972972973	-	151.45714285714286	820.2857142857143	-	843.6
31.71171171171171	-	151.45714285714286	820.2857142857143	-	843.6
33.693693693693696	-	152.9142857142857	827.5714285714286	-	-
35.67567567567568	-	151.45714285714286	824.6571428571428	-	843.6
37.65765765765766	-	151.45714285714286	-	-	833.4
39.63963963963964	152.9142857142857	155.82857142857142	151.45714285714286	-	843.6
41.62162162162162	-	151.45714285714286	830.4857142857143	827.5714285714286	833.4
43.6036036036036	-	151.45714285714286	827.5714285714286	-	843.6
45.585585585585584	-	152.9142857142857	836.3142857142857	-	843.6
47.567567567567565	-	152.9142857142857	830.4857142857143	-	834.8571428571429
49.549549549549546	152.9142857142857	154.37142857142857	833.4	-	843.6
51.531531531531535	831.9428571428572	151.45714285714286	826.1142857142858	-	830.4857142857143
53.513513513513516	843.6	842.1428571428571	814.4571428571429	-	834.8571428571429
55.4954954954955	831.9428571428572	152.9142857142857	815.9142857142857	-	821.7428571428571
57.47747747747748	-	151.45714285714286	811.5428571428571	-	817.3714285714286
59.45945945945946	-	840.6857142857143	792.6	-	817.3714285714286
61.44144144144144	-	151.45714285714286	778.0285714285715	-	772.2
63.42342342342342	-	152.9142857142857	751.8	-	767.8285714285714
65.4054054054054	152.9142857142857	154.37142857142857	779.4857142857143	-	152.9142857142857
67.38738738738739	152.9142857142857	154.37142857142857	808.6285714285714	-	817.3714285714286
69.36936936936937	-	152.9142857142857	807.1714285714286	-	813.0
71.35135135135135	830.4857142857143	839.2285714285714	813.0	-	827.5714285714286
73.33333333333333	829.0285714285715	152.9142857142857	823.2	151.45714285714286	827.5714285714286
75.31531531531532	-	152.9142857142857	827.5714285714286	-	831.9428571428572
77.29729729729729	-	152.9142857142857	827.5714285714286	-	843.6
79.27927927927928	-	152.9142857142857	829.0285714285715	-	833.4
81.26126126126127	163.1142857142857	151.45714285714286	829.0285714285715	-	843.6
83.24324324324324	-	152.9142857142857	829.0285714285715	-	833.4
85.22522522522523	-	152.9142857142857	826.1142857142858	-	843.6
87.2072072072072	-	152.9142857142857	823.2	-	842.1428571428571
89.1891891891892	-	152.9142857142857	823.2	-	842.1428571428571
91.17117117117117	-	152.9142857142857	826.1142857142858	-	843.6
93.15315315315316	152.9142857142857	154.37142857142857	-	-	-
95.13513513513513	-	152.9142857142857	-	-	-
97.11711711711712	-	152.9142857142857	-	151.45714285714286	-
99.09909909909909	831.9428571428572	152.9142857142857	-	-	456.0

Figure:

Gd BS SS TO TQ "H TS Fast Clock Frequency (in MHz) (a) Fault Space Frequency	Waat Occurrence Transformation z SBU			
	194.0 160.0 147.0	131.0 100.0 197.0	211.0 196.0 204.0	130.0 139.0 149.0
0.0	-40.65746421267894	153.12576687116564	151.86196319018404	155.65337423312883
1.9572953736654803	-40.65746421267894	154.38957055214723	-	-
3.9145907473309607	-22.542944785276074	157.33844580777097	-	151.86196319018404
5.871886120996441	11.15848670756646	155.23210633946832	-41.078732106339466	154.38957055214723
7.829181494661921	57.076687116564415	157.75971370143148	-41.078732106339466	151.86196319018404
9.786476868327401	-41.078732106339466	157.75971370143148	98.78220858895705	153.54703476482618
11.743772241992882	-41.078732106339466	156.91717791411043	-	155.65337423312883
13.701067615658364	135.85378323108384	157.75971370143148	-	155.65337423312883
15.658362989323843	142.17280163599182	155.65337423312883	-	154.81083844580778
17.615658362989326	-41.078732106339466	155.65337423312883	151.86196319018404	154.38957055214723
19.572953736654803	-41.078732106339466	155.23210633946832	-	154.38957055214723
21.530249110320284	-41.078732106339466	155.65337423312883	152.28323108384458	153.54703476482618
23.487544483985765	151.019427402863	154.38957055214723	152.28323108384458	156.49591002044988
25.444839857651246	-41.078732106339466	155.65337423312883	-	156.91717791411043
27.402135231316727	-41.078732106339466	157.33844580777097	-	-
29.359430604982208	-40.65746421267894	155.65337423312883	-	154.38957055214723
31.316725978647685	-40.65746421267894	157.75971370143148	-	154.81083844580778
33.27402135231317	-40.65746421267894	155.23210633946832	-	154.38957055214723
35.23131672597865	-40.65746421267894	156.91717791411043	-	152.28323108384458
37.188612099644125	-41.078732106339466	155.65337423312883	-	154.81083844580778
39.145907473309606	-41.078732106339466	155.65337423312883	-	153.96830265848672
41.10320284697509	-40.65746421267894	157.75971370143148	-	154.38957055214723
43.06049822064057	-41.078732106339466	155.65337423312883	-	154.38957055214723
45.01779359430605	-41.078732106339466	157.75971370143148	-	155.23210633946832
46.97508896797153	-41.078732106339466	152.28323108384458	154.38957055214723	-
48.93238434163701	153.96830265848672	152.28323108384458	153.54703476482618	146.80674846625766
50.88967971530249	156.49591002044988	148.91308793456034	-	146.38548057259715
52.84697508896797	155.23210633946832	140.48773006134968	-41.078732106339466	143.01533742331287
54.804270462633454	154.38957055214723	143.85787321063395	152.70449897750512	141.75153374233128
56.761565836298935	154.81083844580778	127.84969325153375	-41.078732106339466	129.53476482617586
58.718861209964416	154.38957055214723	124.05828220858896	-	118.16053169734153
60.67615658362989	155.65337423312883	126.58588957055215	154.38957055214723	-
62.63345195729537	154.81083844580778	135.43251533742333	152.70449897750512	129.11349693251535
64.59074733096085	155.65337423312883	131.219836400818	-	-
66.54804270462634	157.33844580777097	146.38548057259715	155.65337423312883	152.70449897750512
68.50533807829181	156.91717791411043	154.81083844580778	156.07464212678937	149.33435582822085
70.4626334519573	155.65337423312883	153.96830265848672	154.81083844580778	-
72.41992882562278	-	155.23210633946832	-40.65746421267894	152.28323108384458
74.37722419928825	-	155.23210633946832	-40.65746421267894	154.38957055214723
76.33451957295374	-	157.75971370143148	-40.65746421267894	152.28323108384458
78.29181494661921	-	155.65337423312883	-40.65746421267894	154.81083844580778
80.2491103202847	-	157.75971370143148	-41.078732106339466	153.96830265848672
82.20640569395017	-	157.33844580777097	-40.65746421267894	153.96830265848672
84.16370106761566	-40.236196319018404	157.75971370143148	-	154.38957055214723
86.12099644128114	-40.65746421267894	157.75971370143148	-	-
88.07829181494662	-40.65746421267894	155.23210633946832	-	-
90.0355871886121	-40.65746421267894	158.60224948875256	-	-
91.99288256227759	-40.65746421267894	-	-	-
93.95017793594306	-41.078732106339466	-	-40.65746421267894	-
95.90747330960853	-40.65746421267894	-	-	-
97.86476868327402	-41.078732106339466	-	-14.538854805725972	-
99.8220640569395	-15.381390593047033	-39.39366053169734	-33.074642126789364	-

Figure:

Fm Cluck Frequency (in m m) n ul n m p u nhlmIO	Fault qurzence Frequency		
	161.0 235.0 239.0	246.0 185.0 181.0	197.0 168.0 247.0
124.0	249.20792079207922	-	-
124.24	249.20792079207922	-	-
124.48	249.20792079207922	-	-
124.72	249.6039603960396	-	235.74257425742573
124.96	249.20792079207922	-	235.34653465346534
125.2	249.6039603960396	-	232.5742574257426
125.44	249.6039603960396	-	236.53465346534654
125.68	249.20792079207922	118.51485148514851	233.36633663366337
125.92	249.6039603960396	-	236.53465346534654
126.16	249.6039603960396	-	233.76237623762376
126.4	249.6039603960396	177.12871287128712	236.13861386138615
126.64	-	195.74257425742573	232.5742574257426
126.88	249.6039603960396	-	236.53465346534654
127.12	249.6039603960396	-	233.76237623762376
127.36	249.6039603960396	-	236.53465346534654
127.6	249.6039603960396	-	232.97029702970298
127.84	-	-	236.53465346534654
128.08	249.6039603960396	-	233.76237623762376
128.32	-	-	235.74257425742573
128.56	-	-	236.13861386138615
128.8	-	-	235.74257425742573
129.04	-	-	236.13861386138615
129.28	-	-	233.36633663366337
129.52	-	-	236.53465346534654
129.76	-	-	233.76237623762376
130.0	-	-	235.74257425742573
130.24	-	-	229.40594059405942
130.48	249.6039603960396	231.3861386138614	229.40594059405942
130.72	-	233.36633663366337	229.009900990099
130.96	249.6039603960396	-	232.97029702970298
131.2	249.6039603960396	-	231.3861386138614
131.44	249.6039603960396	234.95049504950495	233.76237623762376
131.68	249.6039603960396	234.15841584158414	229.40594059405942
131.92	249.6039603960396	-	225.44554455445544
132.16	-	-	225.04950495049505
132.4	249.6039603960396	-	228.21782178217822
132.64	249.6039603960396	-	229.009900990099
132.88	249.6039603960396	-	233.76237623762376
133.12	249.6039603960396	235.74257425742573	234.55445544554456
133.36	249.6039603960396	-	233.36633663366337
133.6	249.6039603960396	-	236.13861386138615
133.84	249.6039603960396	-	233.76237623762376
134.08	249.6039603960396	50.396039603960396	236.93069306930693
134.32	249.6039603960396	-	234.15841584158414
134.56	-	-	235.74257425742573
134.8	249.6039603960396	-	233.76237623762376
135.04	-	-	236.93069306930693
135.28	249.6039603960396	-	-
135.52	-	-	-
135.76	-	-	-

þÿFigure: U) Flu."- DPGL'C AIGHSIDIIIIHHDH Z DDU

Fast Clnvk Frmrlucrw)r (in MI In) In In L n In l J Quincy	Fault Occurrence Frequency		
	216.0 186.0 169.0	158.0 140.0 241.0	190.0 137.0 180.0
124.0	-	-	24.652087475149106
124.23920265780731	-	-	-
124.47840531561462	-	-	-
124.71760797342192	-	-	-
124.95681063122923	-	91.05367793240556	-
125.19601328903654	-	91.65009940357852	-
125.43521594684385	-	90.85487077534792	-
125.67441860465117	80.31809145129225	91.84890656063618	-
125.91362126245848	70.17892644135189	92.44532803180914	93.43936381709742
126.15282392026577	48.31013916500994	91.65009940357852	-
126.39202657807309	8.548707753479125	92.44532803180914	-
126.6312292358804	7.157057654075547	91.65009940357852	-
126.87043189368771	61.232604373757454	92.2465208747515	-
127.10963455149502	88.86679920477137	91.45129224652088	-
127.34883720930233	-	91.45129224652088	-
127.58803986710963	-	91.05367793240556	90.25844930417495
127.82724252491694	-	90.65606361829026	-
128.06644518272427	-	90.85487077534792	93.43936381709742
128.30564784053155	-	91.25248508946322	-
128.54485049833886	-	91.25248508946322	-
128.78405315614617	-	91.84890656063618	-
129.02325581395348	-	92.44532803180914	-
129.2624584717608	-	91.84890656063618	-
129.5016611295681	-	90.4572564612326	-
129.74086378737542	92.44532803180914	91.65009940357852	92.04771371769384
129.98006644518273	-	91.05367793240556	93.24055666003976
130.21926910299004	92.44532803180914	90.25844930417495	91.84890656063618
130.45847176079735	92.44532803180914	87.8727634194831	90.85487077534792
130.69767441860466	92.2465208747515	87.47514910536779	-
130.93687707641197	92.44532803180914	85.48707753479125	-
131.17607973421926	92.84294234592446	85.2882703777336	-
131.41528239202657	92.44532803180914	88.27037773359841	91.45129224652088
131.65448504983388	92.44532803180914	89.06560636182903	91.45129224652088
131.8936877076412	92.04771371769384	88.66799204771372	-
132.1328903654485	91.45129224652088	87.07753479125249	-
132.37209302325581	92.44532803180914	89.26441351888668	91.84890656063618
132.61129568106313	92.44532803180914	89.06560636182903	91.84890656063618
132.85049833887044	92.04771371769384	91.05367793240556	92.44532803180914
133.08970099667775	93.43936381709742	90.0596421471173	92.84294234592446
133.32890365448506	92.44532803180914	91.45129224652088	92.04771371769384
133.56810631229237	93.63817097415507	90.85487077534792	93.24055666003976
133.80730897009965	92.44532803180914	91.65009940357852	92.04771371769384
134.04651162790697	93.43936381709742	90.25844930417495	92.84294234592446
134.28571428571428	92.2465208747515	91.05367793240556	91.84890656063618
134.5249169435216	93.04174950298211	92.04771371769384	92.6441351888668
134.7641196013289	92.44532803180914	91.25248508946322	92.04771371769384
135.0033222591362	-	91.65009940357852	-
135.24252491694352	-	-	-
135.48172757475083	-	-	-
135.72093023255815	-	-	-
135.96013289036546	-	-	24.85089463220676

Figure: (b) Fault Space Transformation : SBDBU

Fail Cluck Frequvnry (in MHz)	Fault Occurrence Frequency	
	229.0 167.0 149.0	132.0 117.0 215.0
124.0	-	-
124.23801652892563	-	-
124.47603305785124	-	-
124.71404958677687	-	-
124.95206611570248	90.2	91.2
125.1900826446281	74.2	91.8
125.42809917355372	60.8	91.2
125.66611570247935	35.2	91.8
125.90413223140496	7.6	91.6
126.14214876033058	28.2	91.8
126.3801652892562	54.6	92.8
126.61818181818182	70.4	91.8
126.85619834710744	77.2	90.6
127.09421487603306	80.0	91.0
127.33223140495868	87.6	92.2
127.5702479338843	88.8	91.6
127.80826446280992	-	91.6
128.04628099173553	-	92.2
128.28429752066117	-	91.8
128.52231404958678	-	91.8
128.7603305785124	-	92.2
128.998347107438	-	92.8
129.23636363636365	-	92.0
129.47438016528926	-	91.6
129.71239669421487	-	91.8
129.9504132231405	-	92.8
130.18842975206613	92.0	90.4
130.42644628099174	92.2	87.6
130.66446280991735	92.6	87.6
130.90247933884297	93.4	90.0
131.1404958677686	92.6	85.4
131.37851239669422	91.8	74.0
131.61652892561983	91.8	73.8
131.85454545454544	92.6	85.0
132.0925619834711	91.8	85.2
132.3305785123967	92.4	86.2
132.5685950413223	91.4	87.6
132.80661157024792	92.4	88.0
133.04462809917356	92.4	87.8
133.28264462809918	92.2	90.6
133.5206611570248	-	93.2
133.7586776859504	-	92.2
133.99669421487604	-	92.6
134.23471074380166	-	92.0
134.47272727272727	-	92.4
134.71074380165288	-	92.0
134.94876033057852	-	90.6
135.18677685950414	-	-
135.42479338842975	-	-
135.66280991735536	-	-
135.900826446281	32.2	-

Figure:

Past ClOuk Frequency (in MHz)	Fault Occurrence quuency		
	244.0 208.0 190.0	159.0 132.0 218.0	189.0 220.0 235.0
124.0	-	-	-
124.23920265780731	-	-	-
124.47840531561462	-	-	-
124.71760797342192	-	-	-
124.95681063122923	82.73809523809524	90.47619047619048	99.8015873015873
125.19601328903654	44.04761904761905	92.06349206349206	-
125.43521594684385	7.5396825396825395	93.05555555555556	-
125.67441860465117	20.03968253968254	92.06349206349206	-
125.91362126245848	29.761904761904763	93.05555555555556	-
126.15282392026577	37.5	92.06349206349206	-
126.39202657807309	45.833333333333336	93.25396825396825	90.27777777777777
126.6312292358804	59.523809523809526	91.66666666666667	-
126.87043189368771	79.16666666666667	92.85714285714286	-
127.10963455149502	85.91269841269842	91.86507936507937	-
127.34883720930233	88.2936507936508	90.67460317460318	-
127.58803986710963	89.68253968253968	92.85714285714286	-
127.82724252491694	-	90.87301587301587	-
128.06644518272427	-	92.85714285714286	-
128.30564784053155	-	90.47619047619048	-
128.54485049833886	-	93.05555555555556	-
128.78405315614617	-	92.26190476190476	-
129.02325581395348	-	93.05555555555556	48.214285714285715
129.2624584717608	-	91.86507936507937	-
129.5016611295681	-	93.05555555555556	-
129.74086378737542	92.06349206349206	90.07936507936508	-
129.98006644518273	92.46031746031746	89.28571428571429	-
130.21926910299004	92.06349206349206	85.51587301587301	-
130.45847176079735	90.67460317460318	83.92857142857143	-
130.69767441860466	91.86507936507937	80.55555555555556	-
130.93687707641197	93.25396825396825	78.37301587301587	-
131.17607973421926	91.86507936507937	70.03968253968254	-
131.41528239202657	91.46825396825396	55.75396825396825	-
131.65448504983388	92.65873015873017	53.37301587301587	-
131.8936877076412	93.25396825396825	59.72222222222222	-
132.1328903654485	92.85714285714286	63.69047619047619	-
132.37209302325581	92.46031746031746	69.04761904761905	-
132.61129568106313	90.87301587301587	74.60317460317461	-
132.85049833887044	92.65873015873017	76.78571428571429	-
133.08970099667775	92.85714285714286	80.15873015873017	-
133.32890365448506	92.46031746031746	83.73015873015873	-
133.56810631229237	91.26984126984127	89.48412698412699	-
133.80730897009965	92.46031746031746	89.28571428571429	-
134.04651162790697	93.25396825396825	91.46825396825396	-
134.28571428571428	92.46031746031746	90.47619047619048	-
134.5249169435216	92.46031746031746	91.46825396825396	-
134.7641196013289	92.65873015873017	91.26984126984127	-
135.0033222591362	-	93.25396825396825	-
135.24252491694352	-	-	-
135.48172757475083	-	-	-
135.72093023255815	-	-	-
135.960132890365 46	17.658730158730158	-	36.111111111111114

Figure:

TABLE 3: Fault Distribution

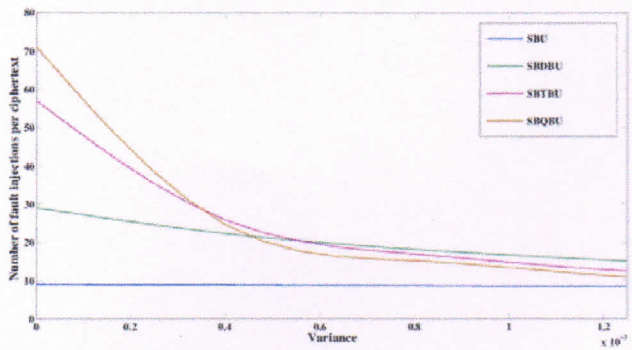
(a) Fault Distribution - Time Redundancy

Fast Clock Frequency (MHz)	FF	SBU	SBDBU	SBTBU	SBQBU	OSB	MB
125.0	512	0	0	0	0	0	0
125.1	503	9	0	0	0	0	0
125.2	489	22	1	0	0	0	0
125.3	456	50	6	0	0	0	0
125.4	425	59	22	6	0	0	0
125.5	396	45	43	28	0	0	0
125.6	351	34	112	32	0	0	0
125.7	303	23	101	85	0	0	0
125.8	260	11	55	86	0	0	0
125.9	208	5	46	147	6	0	0
126.0	176	1	39	228	68	0	0
126.1	143	0	18	211	136	4	0
126.2	115	0	10	94	178	15	0
126.3	101	0	8	95	251	49	8
126.4	65	0	9	45	232	141	20
126.5	32	0	5	16	131	187	141
126.6	13	0	3	8	98	101	289
126.7	5	0	1	4	32	112	358
126.8	0	0	1	2	5	105	399
126.9	0	0	1	2	3	88	421
127.0	0	0	0	1	2	33	476
127.1	0	0	0	0	1	12	499
127.2	0	0	0	0	0	0	512
127.3	0	0	0	0	0	0	512
127.4	0	0	0	0	0	0	512
127.5	0	0	0	0	0	0	512

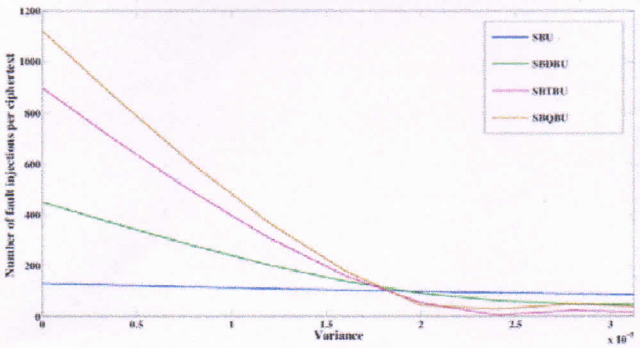
(b) Fault Distribution - Hardware Redundancy

Fast Clock Frequency (MHz)	FF	SBU	SBDBU	SBTBU	SBQBU	OSB	MB
70.0	512	0	0	0	0	0	0
70.1	512	0	0	0	0	0	0
70.2	504	8	0	0	0	0	0
70.3	475	34	3	0	0	0	0
70.4	460	47	5	0	0	0	0
70.5	416	63	29	4	0	0	0
70.6	378	38	71	25	0	0	0
70.7	345	29	120	32	0	0	0
70.8	293	21	164	28	0	0	0
70.9	234	14	120	144	2	0	0
71.0	216	4	39	247	6	0	0
71.1	189	2	35	220	66	0	0
71.2	130	0	15	180	176	11	0
71.3	105	0	10	104	278	15	0
71.4	83	0	10	66	227	100	26
71.5	50	0	8	46	157	162	90
71.6	27	0	5	16	113	125	226
71.7	21	0	4	10	98	118	261
71.8	13	0	3	6	50	103	337
71.9	7	0	3	5	21	107	369
72.0	5	0	3	2	10	99	393
72.1	2	0	1	1	8	44	456
72.2	1	0	0	1	6	19	485
72.3	1	0	0	0	2	8	501
72.4	0	0	0	0	1	5	506
72.5	0	0	0	0	0	0	512

Fig. 4: Number of Fault Attacks per Faulty Ciphertext vs Variance of Fault Probability Distribution



(a) Adversary has perfect control over target byte



(b) Adversary has no control over target byte

recover the full key under different fault models. In the second half, we vary the probability distribution for each fault model to confirm the correlation of the bias with the fault collision probability, as described by Equation 2. We quantify the bias of the fault model using the variance of the fault probability distribution, and the fault collision probability by the number of fault injections required per faulty ciphertext.

TABLE 6: Number Of Faulty Ciphertexts Required To Guess the Entire Key With 99% Probability

Round	Fault Model	N_C
8	SBU	320-340
	SBDBU	580-600
	SBTBU	1000-1040
	SBQBU	1900-2000
9	SBU	288-320
	SBDBU	608-640
	SBTBU	832-880
	SBQBU	1360-1440

5.3.1 Simulation: Part-1

In this part of the simulation, we assume identical faults in both the original and redundant computation rounds and aim to estimate the average number of faulty ciphertexts required to recover the entire key. Note that since the actual attack procedure is independent of the countermeasure scheme being targeted (time or hardware redundancy), the simulation results are presented for a general attack on either countermeasure scheme.

In the simulation, a byte of the state at the desired attack point is chosen at random and then fault is introduced into a certain number of bits belonging to that byte, varying from 1 to 4. Note that these bits are also chosen at random. We simulate the attacks in rounds 8 and 9 respectively. In each case, the appropriate distinguisher function is used to choose the key hypothesis. Table 6 summarizes the number of faulty ciphertexts required for each fault model to guess the entire 128-bit key with 99% accuracy for the attacks on rounds 8 and 9.

5.3.2 Simulation: Part-2

In the second half of the simulation, we varied the degree of bias for each fault model by controlling the variance of the

(h) Adversary has nu ramtul over targvt bytv					
	113.0 157.0 188.0	196.0 121.0 213.0	168.0 182.0 111.0	186.0 133.0 123.0	148.0 105.0 116.0
1.1	19.30116472545757	37.2712146422629	71.3810316139767	95.34109816971714	-
1.2476149176062448	23.12811980033278	39.43427620632279	72.21297836938436	95.17470881863561	-
1.3952298352124892	27.12146422628952	42.26289517470882	73.37770382695507	95.34109816971714	0.9983361064891847
1.542844752818734	30.116472545757073	45.257903494176375	74.70881863560732	95.6738768718802	95.50748752079866
1.6904596704249784	33.44425956738769	47.42096505823627	-	95.84026622296173	95.6738768718802
1.838074588031223	36.605657237936775	50.41597337770383	76.7054908485857	96.00665557404326	50.582362728785355
1.9856895056374677	40.09983361064892	53.24459234608985	77.37104825291182	96.1730449251248	-
2.133304423243712	43.427620632279535	55.074875207986686	78.86855241264558	96.33943427620632	-
2.280919340849957	46.422628951747086	57.90349417637271	79.53410981697171	96.33943427620632	95.84026622296173
2.4285342584562013	50.08319467554077	60.39933444259567	81.03161397670549	96.00665557404326	-
2.576149176062446	53.41098169717138	63.061564059900164	82.19633943427621	96.1730449251248	-
2.7237640936686907	56.07321131447588	65.22462562396007	83.19467554076539	96.33943427620632	-
2.871379011274935	58.901830282861894	67.72046589018302	84.02662229617304	96.33943427620632	-
3.0189939288811796	62.06322795341098	69.88352745424292	-	96.50582362728785	0.831946755407654
3.1666088464874242	64.89184692179701	72.71214642262895	85.35773710482529	96.50582362728785	72.04658901830283
3.314223764093669	67.88685524126456	74.87520798668885	87.0216306156406	96.50582362728785	-
3.4618386816999136	71.3810316139767	76.7054908485857	88.18635607321131	97.33777038269551	-
3.609453599306158	74.04326123128119	79.03494176372712	89.01830282861897	97.17138103161398	79.53410981697171
3.757068516912403	76.53910149750416	80.86522462562397	89.51747088186356	97.33777038269551	0.831946755407654
3.904683434518647	78.53577371048253	82.86189683860233	-	97.00499168053244	83.36106489184692
4.052298352124891	80.86522462562397	84.69217970049917	91.34775374376039	97.00499168053244	84.69217970049917
4.1999132697311365	83.52745424292846	87.0216306156406	92.34608985024958	0.9983361064891847	-
4.347528187337381	86.02329450915141	88.51913477537438	93.34442595673877	97.33777038269551	-
4.495143104943626	88.51913477537438	90.34941763727122	93.34442595673877	97.50415973377704	0.831946755407654
4.64275802254987	90.68219633943427	92.51247920133112	94.50915141430949	97.67054908485856	97.33777038269551
4.790372940156114	92.34608985024958	93.84359400998336	95.17470881863561	97.67054908485856	-
4.937987857762359	94.17637271214642	95.50748752079866	95.84026622296173	97.50415973377704	95.6738768718802
5.085602775368605	95.84026622296173	97.00499168053244	-	97.67054908485856	97.50415973377704
5.233217692974849	97.67054908485856	98.33610648918469	97.33777038269551	-	-
5.380832610581093	99.66722129783693	-	97.50415973377704	97.8369384359401	-
5.528447528187337	-	-	97.67054908485856	-	-
5.6760624457935815	-	-	98.66888519134775	98.16971713810317	-
5.8236773633998276	-	-	99.50083194675541	98.00332778702163	-
5.971292281006072	-	-	-	98.00332778702163	0.9983361064891847
6.118907198612316	-	-	99.83361064891847	98.50249584026622	0.9983361064891847
6.26652211621856	-	-	-	98.66888519134775	97.8369384359401
6.414137033824806	-	-	-	98.66888519134775	97.8369384359401
6.5617519514310505	-	-	-	98.50249584026622	-
6.709366869037295	37.93677204658902	28.119800332778702	19.13477537437604	98.00332778702163	-
6.856981786643539	37.770382695507486	28.618968386023294	19.13477537437604	98.16971713810317	-
7.004596704249783	37.93677204658902	28.119800332778702	19.30116472545757	10.316139767054908	-
7.152211621856029	27.78702163061564	9.317803660565724	-	10.98169717138103	19.966722129783694
7.2998265394622734	8.6522462562396	10.149750415973378	37.770382695507486	38.76871880199667	10.316139767054908
7.447441457068518	36.7720465890183	28.452579034941763	18.63560732113145	99.00166389351081	28.951747088186355
7.595056374674762	-	18.80199667221298	-	-	28.286189683860233
7.742671292281006	-	-	-	99.00166389351081	98.66888519134775
7.890286209887252	-	-	-	98.83527454242929	-
8.037901127493496	-	-	-	99.16805324459234	-
8.18551604509974	-	0.9983361064891847	-	99.16805324459234	98.66888519134775
8.333130962705985	-	-	-	99.33444259567388	98.66888519134775
8.480745880312229	-	-	-	0.831946755407654	98.66888519134775

þÿFigure: \ lim! ll" (a) Adversary has perfect control over target byte

I VIM (a) Adversary has perfect control over target byte						
	84.0 125.0 194.0	151.0 89.0 213.0	132.0 150.0 109.0	179.0 107.0 107.0	160.0 75.0 79.0	148.0 141.0 124.0
-1.0	30.858085808580856	43.06930693069307	-	-	-	70.95709570957095
-0.9612334801762115	34.81848184818482	45.37953795379538	70.95709570957095	-	-	71.45214521452145
-0.9224669603524229	38.77887788778878	48.18481848184818	71.61716171617162	-	94.55445544554455	72.27722772277228
-0.8837004405286344	43.06930693069307	51.15511551155115	72.27722772277228	-	-	95.04950495049505
-0.8449339207048459	46.039603960396036	53.46534653465346	72.93729372937294	-	94.38943894389439	72.60726072607261
-0.8061674008810573	49.66996699669967	55.775577557755774	73.43234323432343	-	-	95.21452145214522
-0.7674008810572688	53.79537953795379	57.92079207920792	73.76237623762377	-	94.55445544554455	74.25742574257426
-0.7286343612334802	57.0957095709571	60.726072607260726	-	-	94.55445544554455	95.04950495049505
-0.6898678414096917	59.73597359735974	62.211221122112214	74.42244224422443	-	94.38943894389439	74.75247524752476
-0.6511013215859031	62.211221122112214	64.35643564356435	75.08250825082509	-	94.38943894389439	75.41254125412541
-0.6123348017621145	65.67656765676567	66.33663366336634	75.9075907590759	-	94.55445544554455	95.04950495049505
-0.573568281938326	67.82178217821782	68.64686468646865	75.9075907590759	-	-	76.4026402640264
-0.5348017621145374	70.62706270627062	69.96699669966996	76.4026402640264	-	94.38943894389439	76.73267326732673
-0.4960352422907489	72.60726072607261	71.2871287128713	76.8976897689769	-	94.38943894389439	77.06270627062706
-0.4572687224669604	74.42244224422443	72.93729372937294	77.22772277227723	-	94.38943894389439	77.72277227722772
-0.41850220264317184	76.56765676567657	74.25742574257426	-	-	1.155115511551155	77.72277227722772
-0.3797356828193833	77.88778877887789	75.41254125412541	-	-	1.3201320132013201	94.71947194719472
-0.34096916299559477	79.53795379537954	76.73267326732673	-	-	94.55445544554455	78.38283828382838
-0.3022026431718061	80.85808580858085	78.05280528052805	78.7128712871287	-	94.55445544554455	78.87788778877888
-0.2634361233480176	81.35313531353135	78.21782178217822	79.53795379537954	-	-	79.20792079207921
-0.22466960352422904	82.50825082508251	78.87788778877888	-	-	-	95.04950495049505
-0.1859030837004405	83.16831683168317	79.70297029702971	-	-	-	94.88448844884489
-0.14713656387665197	83.82838283828383	80.03300330033004	-	-	80.1980198019802	94.71947194719472
-0.10837004405286343	84.65346534653466	81.35313531353135	80.1980198019802	-	94.71947194719472	80.52805280528052
-0.0696035242290749	84.98349834983499	81.51815181518151	80.85808580858085	-	-	81.02310231023102
-0.03083700440528636	84.81848184818482	81.68316831683168	80.6930693069307	-	-	95.04950495049505
0.007929515418502175	85.31353135313532	82.01320132013201	81.02310231023102	-	94.71947194719472	81.35313531353135
0.04669603524229071	85.8085808580858	82.67326732673267	81.35313531353135	-	-	81.68316831683168
0.08546255506607925	85.97359735973598	82.83828382838284	-	-	-	81.51815181518151
0.12422907488986779	86.13861386138613	83.33333333333333	82.17821782178218	-	94.71947194719472	82.01320132013201
0.16299559471365632	86.13861386138613	83.33333333333333	82.17821782178218	-	-	82.67326732673267
0.20176211453744486	86.63366336633663	83.99339933993399	82.34323432343234	-	94.88448844884489	82.83828382838284
0.2405286343612334	86.79867986798679	84.15841584158416	-	-	-	82.50825082508251
0.27929515418502193	86.96369636963696	84.48844884488449	82.83828382838284	-	94.88448844884489	83.16831683168317
0.31806167400881047	86.96369636963696	84.81848184818482	-	-	1.4851485148514851	95.21452145214522
0.3568281938325992	87.29372937293729	84.98349834983499	83.33333333333333	-	94.88448844884489	83.66336633663366
0.39559471365638776	87.7887788778878	85.14851485148515	83.33333333333333	-	94.71947194719472	83.99339933993399
0.4343612334801763	87.95379537953795	85.64356435643565	83.66336633663366	-	95.54455445544555	83.99339933993399
0.47312775330396484	88.11881188118812	86.13861386138613	84.15841584158416	-	-	84.15841584158416
0.5118942731277534	88.44884488448845	86.13861386138613	19.306930693069308	-	-	84.65346534653466
0.5506607929515419	38.44884488448845	28.877887788778878	19.471947194719473	-	9.900990099009901	19.966996699669966
0.5894273127753304	89.10891089108911	28.712871287128714	19.471947194719473	-	94.88448844884489	84.81848184818482
0.628193832599119	18.646864686468646	87.29372937293729	84.98349834983499	-	38.118811881188115	30.363036303630363
0.6669603524229075	89.93399339933994	9.570957095709572	19.471947194719473	-	20.462046204620464	85.14851485148515
0.7057268722466961	37.95379537953795	19.471947194719473	84.98349834983499	-	28.217821782178216	38.44884488448845
0.7444933920704846	90.42904290429043	37.29372937293729	85.47854785478548	-	95.04950495049505	85.8085808580858
0.7832599118942731	90.26402640264027	88.44884488448845	85.31353135313532	-	95.04950495049505	85.97359735973598
0.8220264317180617	90.5940594059406	88.77887788778878	85.64356435643565	-	-	85.97359735973598
0.8607929515418502	90.92409240924093	88.77887788778878	85.97359735973598	-	43.72937293729373	95.54455445544555
0.8995594713656387	91.58415841584159	89.27392739273927	86.13861386138613	-	4.785478547854786	86.46864686468646
0.9383259911894273	91.58415841584159	89.27392739273927	86.46864686468646	-	43.72937293729373	95.54455445544555
0.9770925110132158	91.74917491749174	89.60396039603961	86.13861386138613	-	-	86.96369636963696

Figure: h k of Fault Attacks per Faulty Ciphertext vs Variance of Fault My 'stribution

	130.0 174.0 191.0	201.0 178.0 176.0	195.0 172.0 176.0	147.0 143.0 154.0	103.0 95.0 102.0	111.0 124.0 116.0	131.0 129.0 118.0
0.0	55.223880597014926	-	-	-	-	9.950248756218905	10.447761194029852
1.8612521150592216	9.950248756218905	56.21890547263681	10.447761194029852	-	-	-	-
3.7225042301184432	55.223880597014926	55.97014925373134	3.482587064676617	-	6.7164179104477615	2.736318407960199	0.24875621890547264
5.583756345177665	5.721393034825871	10.696517412935323	1.7412935323383085	0.9950248756218906	1.492537313432836	-	6.218905472636816
7.4450084602368864	55.472636815920396	10.696517412935323	-	2.985074626865672	3.2338308457711444	-	6.7164179104477615
9.306260575296108	2.736318407960199	10.447761194029852	-	-	-	-	56.21890547263681
11.16751269035533	55.472636815920396	10.696517412935323	6.7164179104477615	74.37810945273633	75.12437810945273	28.606965174129353	32.33830845771144
13.028764805414552	30.34825870646766	10.696517412935323	55.97014925373134	74.37810945273633	29.35323383084577	30.597014925373134	34.5771144278607
14.890016920473773	6.218905472636816	-	-	5.721393034825871	-	-	6.7164179104477615
16.751269035532996	2.487562189054726	-	3.9800995024875623	-	5.472636815920398	-	56.21890547263681
18.612521150592215	55.472636815920396	-	6.467661691542289	3.482587064676617	5.223880597014926	10.199004975124378	10.696517412935323
20.473773265651438	55.223880597014926	2.985074626865672	0.24875621890547264	6.218905472636816	-	-	6.7164179104477615
22.33502538071066	55.223880597014926	10.447761194029852	-	-	-	-	-
24.19627749576988	9.950248756218905	10.696517412935323	-	-	-	-	-
26.057529610829103	9.950248756218905	10.696517412935323	10.447761194029852	-	-	-	10.945273631840797
27.918781725888326	9.950248756218905	0.746268656716418	6.7164179104477615	-	0.4975124378109453	-	56.21890547263681
29.780033840947546	55.223880597014926	55.97014925373134	3.482587064676617	2.985074626865672	2.985074626865672	-	0.24875621890547264
31.64128595600677	9.950248756218905	55.97014925373134	10.447761194029852	4.72636815920398	3.2338308457711444	-	6.7164179104477615
33.50253807106599	55.223880597014926	55.97014925373134	10.696517412935323	3.9800995024875623	3.482587064676617	-	6.7164179104477615
35.363790186125215	93.03482587064677	71.64179104477611	74.87562189054727	84.57711442786069	90.54726368159204	45.27363184079602	82.58706467661692
37.22504230118443	33.830845771144276	56.21890547263681	10.696517412935323	90.54726368159204	27.611940298507463	48.756218905472636	51.492537313432834
39.086294416243654	5.970149253731344	10.696517412935323	2.487562189054726	50.995024875621894	37.56218905472637	27.36318407960199	91.29353233830845
40.947546531302876	26.119402985074625	55.97014925373134	2.985074626865672	36.81592039800995	46.26865671641791	11.194029850746269	49.25373134328358
42.8087986463621	72.88557213930348	55.97014925373134	24.378109452736318	46.01990049751244	48.507462686567166	-	56.21890547263681
44.67005076142132	96.76616915422886	18.65671641791045	74.87562189054727	60.19900497512438	90.79601990049751	11.194029850746269	0.24875621890547264
46.53130287648054	55.223880597014926	28.35820895522388	17.412935323383085	15.422885572139304	47.014925373134325	92.7860696517413	96.51741293532338
48.39255499153976	79.1044776119403	52.23880597014925	11.194029850746269	46.766169154228855	17.412935323383085	56.46766169154229	63.681592039801
50.253807106598984	48.00995024875622	-	25.37313432835821	80.34825870646766	62.93532338308458	37.56218905472637	57.21393034825871
52.11505922165821	5.721393034825871	6.965174129353234	37.56218905472637	22.63681592039801	36.069651741293534	46.766169154228855	81.09452736318408
53.97631133671743	55.223880597014926	52.23880597014925	5.970149253731344	29.104477611940297	2.985074626865672	9.950248756218905	41.29353233830846
55.83756345177665	10.199004975124378	55.97014925373134	34.32835820895522	96.26865671641791	72.636815920398	49.50248756218905	50.24875621890547
57.69881556683587	55.223880597014926	55.97014925373134	10.696517412935323	-	-	9.950248756218905	6.7164179104477615
59.56006768189509	10.199004975124378	-	5.970149253731344	2.736318407960199	5.970149253731344	-	4.72636815920398
61.421319796954315	9.950248756218905	55.72139303482587	6.467661691542289	2.487562189054726	6.467661691542289	-	4.477611940298507
63.28257191201354	55.223880597014926	4.975124378109452	4.477611940298507	-	0.9950248756218906	5.472636815920398	-
65.14382402707275	55.223880597014926	-	56.21890547263681	-	10.696517412935323	-	-
67.00507614213198	55.472636815920396	55.97014925373134	10.447761194029852	-	-	9.950248756218905	-
68.8663282571912	9.950248756218905	-	10.696517412935323	-	-	-	56.21890547263681
70.72758037225043	9.950248756218905	10.696517412935323	10.447761194029852	90.54726368159204	-	-	97.51243781094527
72.58883248730965	9.701492537313433	10.696517412935323	10.447761194029852	71.39303482587064	71.64179104477611	55.472636815920396	97.51243781094527
74.45008460236886	63.18407960199005	10.447761194029852	94.77611940298507	92.03980099502488	96.26865671641791	68.1592039800995	55.97014925373134
76.31133671742809	55.472636815920396	-	10.696517412935323	69.90049751243781	80.09950248756219	57.960199004975124	56.21890547263681
78.1725888324873	57.46268656716418	63.681592039801	68.90547263681592	73.6318407960199	62.93532338308458	70.39800995024876	58.208955223880594
80.03384094754654	79.60199004975124	57.960199004975124	-	74.12935323383084	90.79601990049751	95.77114427860697	58.95522388059702
81.89509306260575	60.69651741293532	10.696517412935323	62.93532338308458	80.59701492537313	70.14925373134328	3.7313432835820897	86.06965174129353
83.75634517766497	71.8905472636816	10.447761194029852	0.9950248756218906	60.9452736318408	-	-	83.83084577114428
85.6175972927242	90.54726368159204	10.696517412935323	83.33333333333333	3.7313432835820897	79.85074626865672	-	97.51243781094527
87.47884940778341	62.43781094527363	4.477611940298507	61.691542288557216	62.93532338308458	58.45771144278607	3.7313432835820897	58.70646766169154
89.34010152284264	9.950248756218905	10.447761194029852	58.208955223880594	72.38805970149254	79.60199004975124	-	97.76119402985074
91.20135363790186	55.472636815920396	63.930348258706466	95.5223880597015	72.88557213930348	74.87562189054727	-	56.21890547263681
93.06260575296108	91.54228855721394	10.447761194029852	92.53731343283582	94.02985074626865	93.78109452736318	96.51741293532338	96.26865671641791
94.9238578680203	9.950248756218905	55.97014925373134	95.5223880597015	93.53233830845771	92.53731343283582	9.950248756218905	95.77114427860697
96.78510998307952	91.29353233830845	10.447761194029852	-	-	-	97.01492537313433	97.51243781094527
98.64636209813875	55.472636815920396	10.447761194029852	-	-	-	-	-

Figure:

Probability ound ault o l NC							
	155.0 98.0 83.0	185.0 185.0 191.0	171.0 235.0 253.0	162.0 148.0 152.0	127.0 118.0 128.0	199.0 200.0 196.0	181.0 205.0 193.0
-1.68168165425E11	6.719022687609075	6.980802792321117	6.369982547993019	-	-	-	6.457242582897033
-1.5854546386111444E11	-	0.4363001745200698	6.369982547993019	0.6980802792321117	0.6108202443280978	-	6.457242582897033
-1.4892276229722888E11	1.3961605584642234	0.8726003490401396	6.369982547993019	1.0471204188481675	0.9598603839441536	-	-
-1.3930006073334332E11	6.631762652705061	0.08726003490401396	6.369982547993019	0.9598603839441536	0.34904013961605584	-	6.457242582897033
-1.2967735916945776E11	0.6108202443280978	6.980802792321117	6.369982547993019	1.0471204188481675	0.08726003490401396	-	6.893542757417103
-1.200546576055722E11	6.719022687609075	0.6108202443280978	6.893542757417103	0.4363001745200698	0.6980802792321117	-	6.457242582897033
-1.1043195604168665E11	6.631762652705061	4.363001745200698	6.457242582897033	4.101221640488657	3.6649214659685865	-	5.061082024432809
-1.0080925447780109E11	1.3089005235602094	23.647469458987782	27.050610820244327	9.860383944153577	76.96335078534031	83.59511343804537	97.64397905759162
-9.118655291391553E10	42.32111692844677	23.56020942408377	98.25479930191972	3.8394415357766145	31.762652705061083	42.582897033158815	23.82198952879581
-8.156385135002997E10	41.97207678883071	3.2286212914485164	96.9458987783595	3.7521815008726005	45.11343804537522	0.6980802792321117	20.593368237347295
-7.194114978614441E10	1.2216404886561956	0.5235602094240838	6.457242582897033	0.8726003490401396	0.6108202443280978	-	3.7521815008726005
-6.231844822225885E10	6.719022687609075	0.7853403141361257	6.980802792321117	1.3961605584642234	0.9598603839441536	-	6.806282722513089
-5.269574665837329E10	6.719022687609075	0.9598603839441536	6.457242582897033	-	1.1343804537521816	1.3961605584642234	6.893542757417103
-4.307304509448773E10	6.719022687609075	6.544502617801047	6.980802792321117	1.3089005235602094	6.544502617801047	0.9598603839441536	6.893542757417103
-3.3450343530602173E10	6.719022687609075	6.544502617801047	6.457242582897033	-	0.6108202443280978	6.806282722513089	6.893542757417103
-2.3827641966716614E10	1.3961605584642234	1.3089005235602094	6.980802792321117	0.6980802792321117	0.6980802792321117	6.806282722513089	6.893542757417103
-1.4204940402831055E10	7.2425828970331585	6.544502617801047	0.6108202443280978	-	-	-	-
-4.582238838945496E9	6.719022687609075	6.457242582897033	6.980802792321117	-	6.544502617801047	-	-
5.040462724940063E9	31.67539267015707	73.73472949389179	2.7050610820244327	35.25305410122164	30.977312390924958	84.20593368237347	41.273996509598604
1.4663164288825623E10	48.7783595113438	55.14834205933683	2.8795811518324608	3.5776614310645725	55.410122164048865	6.806282722513089	73.1239092495637
2.4285865852711118E10	7.2425828970331585	6.544502617801047	6.980802792321117	7.155322862129145	-	6.806282722513089	-
3.390856741659674E10	7.155322862129145	6.544502617801047	3.4031413612565444	2.7923211169284468	2.7050610820244327	6.893542757417103	3.3158813263525304
4.35312689804823E10	3.6649214659685865	27.31239092495637	38.65619546247819	42.40837696335078	23.7347294938918	20.767888307155324	41.710296684118674
5.315397054436786E10	7.155322862129145	20.244328097731238	2.181500872600349	24.607329842931936	31.93717277486911	-	3.4904013961605584
6.277667210825342E10	3.4904013961605584	2.181500872600349	6.980802792321117	2.5305410122164047	2.356020942408377	-	-
7.239937367213898E10	7.2425828970331585	6.544502617801047	6.980802792321117	-	6.544502617801047	-	6.980802792321117
8.202207523602454E10	3.6649214659685865	2.356020942408377	3.3158813263525304	3.4904013961605584	2.443280977312391	6.806282722513089	-
9.16447767999101E10	7.2425828970331585	6.544502617801047	34.29319371727749	38.83071553228621	2.356020942408377	6.806282722513089	3.3158813263525304
1.0126747836379565E11	3.6649214659685865	59.33682373472949	16.57940663176265	49.040139616055846	90.31413612565446	28.359511343804538	62.652705061082024
1.1089017992768121E11	7.155322862129145	41.273996509598604	27.137870855148343	38.917975567190226	37.78359511343805	6.806282722513089	2.7923211169284468
1.2051288149156677E11	-	6.544502617801047	3.4031413612565444	3.4904013961605584	-	6.806282722513089	-
1.3013558305545233E11	7.2425828970331585	6.544502617801047	6.980802792321117	-	-	6.806282722513089	-
1.397582846193379E11	7.2425828970331585	6.544502617801047	6.980802792321117	6.719022687609075	2.7050610820244327	-	-
1.4938098618322345E11	7.2425828970331585	3.3158813263525304	2.094240837696335	2.443280977312391	2.268760907504363	3.054101221640489	3.141361256544503
1.59003687747109E11	32.11169284467714	37.609075043630014	38.65619546247819	7.155322862129145	31.93717277486911	6.806282722513089	66.49214659685863
1.6862638931099457E11	31.93717277486911	31.239092495637	2.268760907504363	2.356020942408377	34.29319371727749	31.849912739965095	48.7783595113438
1.7824909087488013E11	6.719022687609075	6.544502617801047	2.268760907504363	2.443280977312391	-	-	2.094240837696335
1.878717924387657E11	3.5776614310645725	6.544502617801047	2.181500872600349	2.6178010471204187	2.443280977312391	3.4031413612565444	3.2286212914485164
1.9749449400265125E11	6.719022687609075	6.544502617801047	2.8795811518324608	3.141361256544503	0.4363001745200698	6.806282722513089	3.4031413612565444
2.071171955665368E11	3.141361256544503	6.544502617801047	2.7923211169284468	3.5776614310645725	3.4904013961605584	6.806282722513089	-
2.1673989713042236E11	6.719022687609075	7.0680628272251305	2.181500872600349	3.2286212914485164	2.268760907504363	-	3.4031413612565444
2.2636259869430792E11	6.719022687609075	6.544502617801047	2.181500872600349	3.5776614310645725	2.268760907504363	-	2.181500872600349
2.3598530025819348E11	3.4904013961605584	6.544502617801047	2.181500872600349	2.443280977312391	3.2286212914485164	6.806282722513089	3.4031413612565444
2.4560800182207904E11	6.719022687609075	6.544502617801047	2.094240837696335	3.6649214659685865	3.141361256544503	6.893542757417103	-
2.552307033859646E11	6.719022687609075	7.0680628272251305	6.980802792321117	-	-	-	-
2.6485340494985016E11	7.2425828970331585	6.544502617801047	7.0680628272251305	-	-	-	-
2.7447610651373572E11	7.2425828970331585	2.443280977312391	83.50785340314137	80.36649214659685	83.94415357766142	-	3.4031413612565444
2.840988080776213E11	6.719022687609075	6.631762652705061	3.4904013961605584	10.645724258289704	13.525305410122163	90.92495636998255	73.64746945898779
2.9372150964150684E11	3.6649214659685865	2.268760907504363	2.181500872600349	2.5305410122164047	2.7050610820244327	3.3158813263525304	-
3.033442112053924E11	48.51657940663176	14.397905759162304	31.413612565445025	0.6108202443280978	1.2216404886561956	28.01047120418848	2.7923211169284468
3.1296691276927795E11	66.49214659685863	83.7696335078534	58.638743455497384	77.39965095986038	84.11867364746946	76.96335078534031	80.71553228621292
3.225896143331635E11	10.122164048865619	45.20069808027923	2.181500872600349	70.15706806282722	52.44328097731239	72.77486910994764	76.61431064572426
3.322123158970491E11	7.2425828970331585	80.27923211169285	6.980802792321117	66.40488656195463	66.66666666666667	-	3.3158813263525304

þÿFigure: buû on (b) Fault Distri'buû on - Hardware RcdImdancy

lility Distribution							
	148.0 154.0 161.0	178.0 164.0 166.0	186.0 211.0 207.0	137.0 132.0 141.0	213.0 209.0 191.0	202.0 147.0 138.0	117.0 124.0 117.0
-5.888801981E9	6.381118881118881	6.555944055944056	6.818181818181818	-	-	-	-
-5.564163686275362E9	0.34965034965034963	1.048951048951049	6.730769230769231	-	-	-	-
-5.239525391550725E9	6.818181818181818	6.468531468531468	6.381118881118881	0.7867132867132867	7.080419580419581	1.2237762237762237	-
-4.914887096826087E9	6.381118881118881	6.555944055944056	0.5244755244755245	0.17482517482517482	6.643356643356643	0.34965034965034963	-
-4.590248802101145E9	0.08741258741258741	6.555944055944056	-	0.26223776223776224	0.8741258741258742	1.048951048951049	-
-4.265610507376812E9	6.818181818181818	1.1363636363636365	-	-	7.080419580419581	6.555944055944056	-
-3.940972212652174E9	6.818181818181818	3.8461538461538463	6.206293706293707	4.108391608391608	1.3111888111888113	6.993006993006993	6.730769230769231
-3.616333917927536 5E9	3.7587412587412588	10.926573426573427	52.7972027972028	0.17482517482517482	56.46853146853147	4.458041958041958	21.24125874125874
-3.291695623202899E9	21.153846153846153	6.555944055944056	79.72027972027972	0.26223776223776224	94.93006993006993	83.39160839160839	9.877622377622378
-2.967057328478261E9	66.6958041958042	21.32867132867133	-	10.751748251748252	45.97902097902098	0.5244755244755245	14.248251748251748
-2.642419033753623 5E9	3.5839160839160837	21.24125874125874	34.00349650349651	38.72377622377623	80.24475524475524	7.080419580419581	80.06993006993007
-2.317807390289855E9	6.381118881118881	6.555944055944056	6.293706293706293	0.5244755244755245	6.643356643356643	-	-
-1.993142444304348E9	6.381118881118881	0.9615384615384616	6.293706293706293	0.6118881118881119	6.643356643356643	-	-
-1.668504149579710 5E9	6.293706293706293	0.6118881118881119	-	0.8741258741258742	6.643356643356643	1.2237762237762237	-
-1.343865854855073E9	0.17482517482517482	6.555944055944056	-	6.468531468531468	7.080419580419581	-	-
-1.019227560130435E9	0.26223776223776224	6.555944055944056	6.293706293706293	0.34965034965034963	7.1678321678321675	-	-
-6.94589265405798E8	6.818181818181818	-	6.293706293706293	0.6118881118881119	7.1678321678321675	-	-
-3.6995097068116E8	6.818181818181818	6.555944055944056	6.381118881118881	6.905594405594406	7.1678321678321675	-	6.643356643356643
-4.531267595652199E7	30.681818181818183	14.423076923076923	17.657342657342657	37.58741258741259	2.797202797202797	21.153846153846153	17.744755244755243
2.79325618768115 04E8	1.9230769230769231	10.839160839160838	3.1468531468531467	44.93006993006993	7.1678321678321675	2.1853146853146854	2.534965034965035
6.039639134927 53E8	6.818181818181818	6.993006993006993	-	6.468531468531468	6.643356643356643	7.080419580419581	-
9.286022082173 91E8	6.381118881118881	-	-	6.468531468531468	6.643356643356643	3.234265734265734	-
1.253240502942029E9	6.818181818181818	34.35314685314685	27.534965034965033	30.594405594405593	6.643356643356643	3.0594405594405596	-
1.577878797666666E9	23.513986013986013	24.912587412587413	23.68881118881119	30.856643356643357	7.080419580419581	16.783216783216783	24.65034965034965
1.902517092391304E9	6.381118881118881	2.272727272727273	2.7097902097902096	-	7.080419580419581	-	2.8846153846153846
2.227155387115942E9	4.370629370629371	15.734265734265735	1.8356643356643356	1.6608391608391608	7.1678321678321675	0.08741258741258741	2.0104895104895104
2.551793681840579E9	3.3216783216783217	2.972027972027972	-	2.7097902097902096	6.730769230769231	2.8846153846153846	-
2.876431976565218E9	6.818181818181818	2.972027972027972	-	35.31468531468531	6.643356643356643	2.8846153846153846	-
3.201070271289854E9	16.695804195804197	10.839160839160838	93.88111888111888	42.13286713286713	94.14335664335664	28.05944055944056	93.96853146853147
3.525708566014492E9	24.737762237762237	49.03846153846154	34.96503496503497	31.73076923076923	7.080419580419581	3.4965034965034967	3.409090909090909
3.850346860739 13E9	6.905594405594406	2.4475524475524475	2.797202797202797	3.1468531468531467	7.1678321678321675	3.4965034965034967	2.6223776223776225
4.174985155463768E9	6.905594405594406	-	-	6.468531468531468	7.080419580419581	-	-
4.499623450188404E9	6.818181818181818	-	-	-	6.643356643356643	-	-
4.824261744913044E9	6.381118881118881	2.972027972027972	2.8846153846153846	3.234265734265734	3.4965034965034967	2.36013986013986	-
5.148900039637 68E9	6.818181818181818	3.0594405594405596	48.25174825174825	38.11188811188811	52.97202797202797	28.40909090909091	59.52797202797203
5.473538334362318E9	31.643356643356643	16.87062937062937	38.72377622377623	27.36013986013986	94.31818181818181	6.643356643356643	94.49300699300699
5.798176629086956E9	2.797202797202797	7.080419580419581	6.818181818181818	3.234265734265734	7.1678321678321675	6.643356643356643	-
6.122814923811592E9	2.1853146853146854	7.080419580419581	3.3216783216783217	2.972027972027972	7.1678321678321675	-	-
6.447453218536 23E9	6.293706293706293	2.8846153846153846	6.118881118881119	4.283216783216783	7.1678321678321675	5.769230769230769	-
6.772091513260 87E9	2.6223776223776225	7.080419580419581	3.409090909090909	-	3.5839160839160837	2.272727272727273	2.1853146853146854
7.096729807985506E9	2.0104895104895104	2.8846153846153846	3.409090909090909	2.6223776223776225	6.730769230769231	-	-
7.421368102710144E9	2.272727272727273	-	3.409090909090909	-	7.1678321678321675	6.730769230769231	-
7.746006397434782E9	2.097902097902098	7.080419580419581	2.6223776223776225	-	6.730769230769231	6.643356643356643	-
8.070644692159418E9	2.0104895104895104	2.4475524475524475	3.1468531468531467	2.972027972027972	7.255244755244755	6.730769230769231	3.409090909090909
8.395282986884058E9	6.468531468531468	2.272727272727273	6.905594405594406	2.097902097902098	6.730769230769231	-	-
8.719921281608696E9	6.468531468531468	6.643356643356643	6.905594405594406	-	7.255244755244755	6.730769230769231	-
9.044559576333332E9	51.83566433566433	69.66783216783217	3.409090909090909	62.5	77.53496503496504	6.643356643356643	-
9.369197871057 97E9	23.776223776223777	42.56993006993007	62.93706293706294	27.272727272727273	59.35314685314685	3.6713286713286712	94.23076923076923
9.693836165782608E9	2.0104895104895104	73.77622377622377	73.33916083916084	73.42657342657343	62.5	3.409090909090909	-
1.001847446050724 4E10	6.381118881118881	8.12937062937063	2.797202797202797	5.594405594405594	15.384615384615385	6.643356643356643	7.43006993006993
1.034311275523188 4E10	2.097902097902098	2.797202797202797	60.05244755244755	80.5944055944056	80.76923076923077	6.643356643356643	74.03846153846153
1.066775104995652 2E10	6.905594405594406	2.6223776223776225	93.88111888111888	13.374125874125873	53.05944055944056	53.14685314685315	59.96503496503497
1.099238934468115 8E10	2.7097902097902096	73.77622377622377	80.85664335664336	69.84265734265735	97.81468531468532	66.60839160839161	90.73426573426573

Figure: (a) Fault Distribution - lime Redundancy