Speeding up Effect-Cause Defect Diagnosis using a Small Dictionary

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Outline

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- Types of Defect Diagnostics Method
- Effect-Cause Defect Diagnosis
- Proposed Work
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Introduction

- With 90nm and smaller feature size designs, the dominant defect type has changed from the random particle defect to the *design-specific systematic defect.*
- High accuracy and throughput is needed to identity design-specific defects for a large number of dies within a short time.

Types of Defect Diagnostic Methods

1. Cause-Effect Diagnosis:

- pre-computes and stores the faulty responses of modeled faults in a dictionary.
- The observed failure responses are compared with the pre-computed failure responses in the dictionary.
- The faults whose pre-computed failure responses have the closest match with the observed failure responses will be chosen as final candidates.

Types of Defect Diagnostic Methods

1. Cause-Effect Diagnosis:

- Fast diagnosis but requires large memory
- Can reduce memory by using pass/fail dictionaries, but may lose diagnosis accuracy due to information loss.

Types of Defect Diagnostic Methods

2. Effect-Cause Diagnosis:

- Only simulates the potential fault candidates obtained by back tracing from failing outputs.
- does not need a large memory to store pre-computed faulty responses, yet maintains a very high diagnosis accuracy.
- Very slow to diagnose a failing chip due to a large number of fault simulations used during diagnosis

Effect-Cause Defect Diagnosis Procedure

There are two phases:

- **Phase 1:** a set of candidate fault sites are determined from the failing test patterns
- **Phase2:** candidate sites are ranked by fault simulating the candidates using passing patterns

Phase 1

- Each failing test pattern **p**, back tracing is used to find a set of faults **Q**

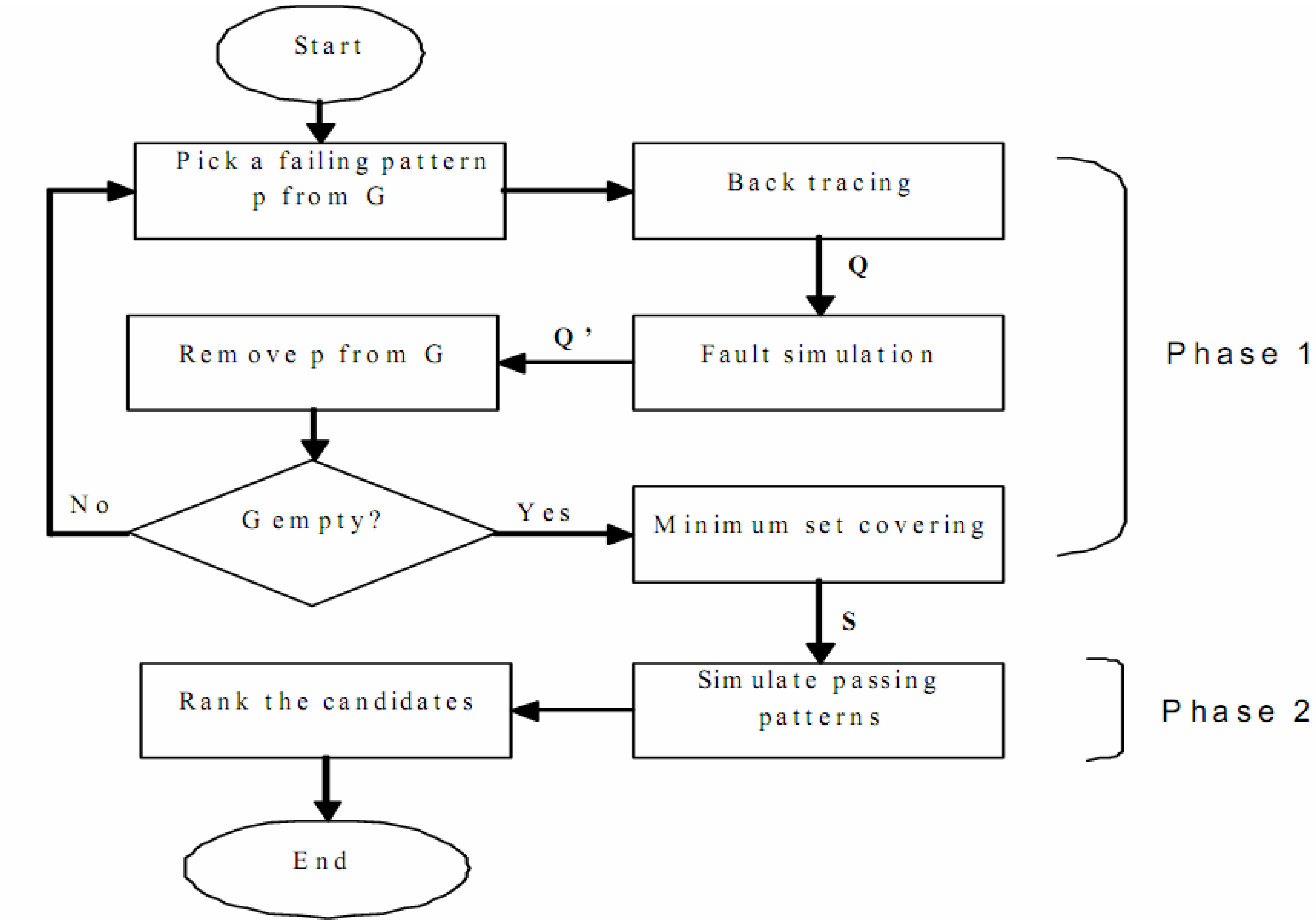
- The faults in **Q** are simulated to find subset **Q’**

- A minimum set covering algorithm is used to find a subset **S**, of minimum size, of the set of faults **Q’**

Phase 2

- The fault candidates in S are simulated over all the passing patterns to find the number of passing pattern mismatches for each candidate.
- Pattern mismatch occurs whenever a candidate fault is detected by a passing pattern
- Candidates are ranked based on a score that is calculated from the number of passing and failing patterns matches or mismatches.

Effect-Cause Defect Diagnosis Flow



Problems of Effect-Cause Diagnosis

There are two run time intensive steps:

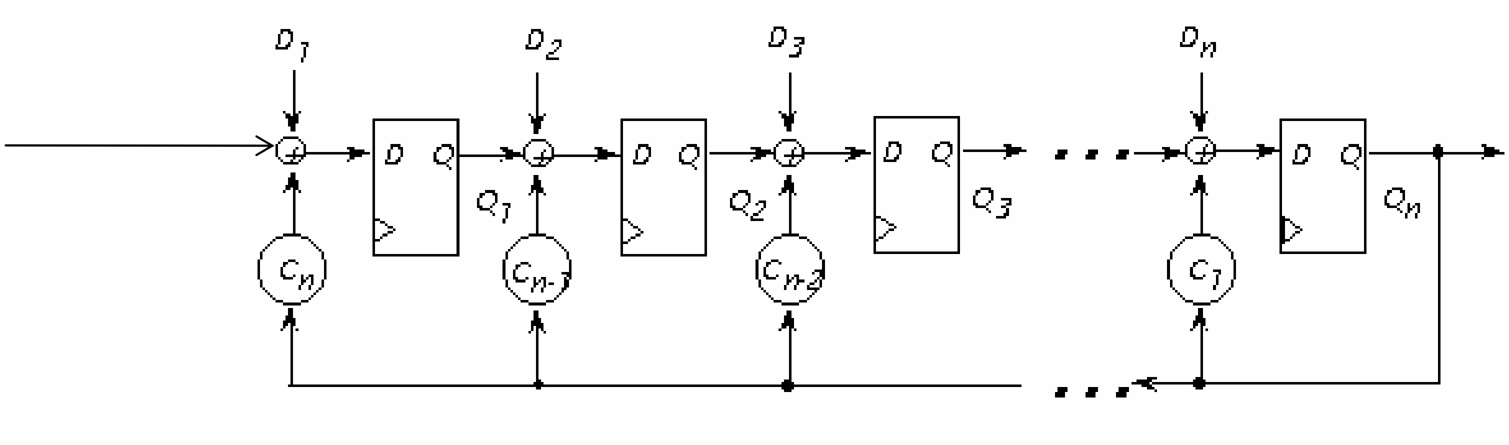
1. **Phase1:** back tracing and fault simulation time in the first phase for faults in Q to obtain the faults in Q'. Back tracing uses a version of CPT and identified faults trigger a large number of events during fault simulation
2. **Phase2:** simulating faults in S using all passing patterns

The Proposed Method

- Combine dictionary based diagnosis with effect-cause diagnosis to speed-up diagnosis.

- use a dictionary of small size to determine an initial list of candidates that explain a failing pattern thus avoiding back tracing.

Multiple Input Single Register (MISR)



Creating the Small Dictionary

- The small dictionary is based on signatures
  → it is like a hash table
- Signatures are computed using a MISR for each fault and test pattern that detects fault
- The identification of each output error is represented by a 32 bit integer and is fed to MISR
- Unique signatures are only stored for each fault
- MISR is 32-bits long with primitive polynomial $1+x+x^{29}+x^{31}+x^{32}$ and seed is set to 0's.

Example

- Test Pattern: T = {T1, T2, T3, T4}
- Fault f is detected by T1, T3, T4
- T1, T3 is observed at output 3 and 15
- T4 is observed at output 7 and 10
- 3 and 15 is fed to MISR to get signature 0000000E
- 7 and 10 is fed to MISR to get signature 00000009
- Fault f in the dictionary now only has:

  {0000000E, 00000009}

Creating Dictionary continued…

- Also in the dictionary, each clock is assigned 1 bit to indicate whether it is associated with the scan cells where the effects of a fault are observed
- Size of dictionary:

$$= 32 \cdot U \cdot F + F \cdot C$$

where,

F: the number of faults

U: average number of unique signatures

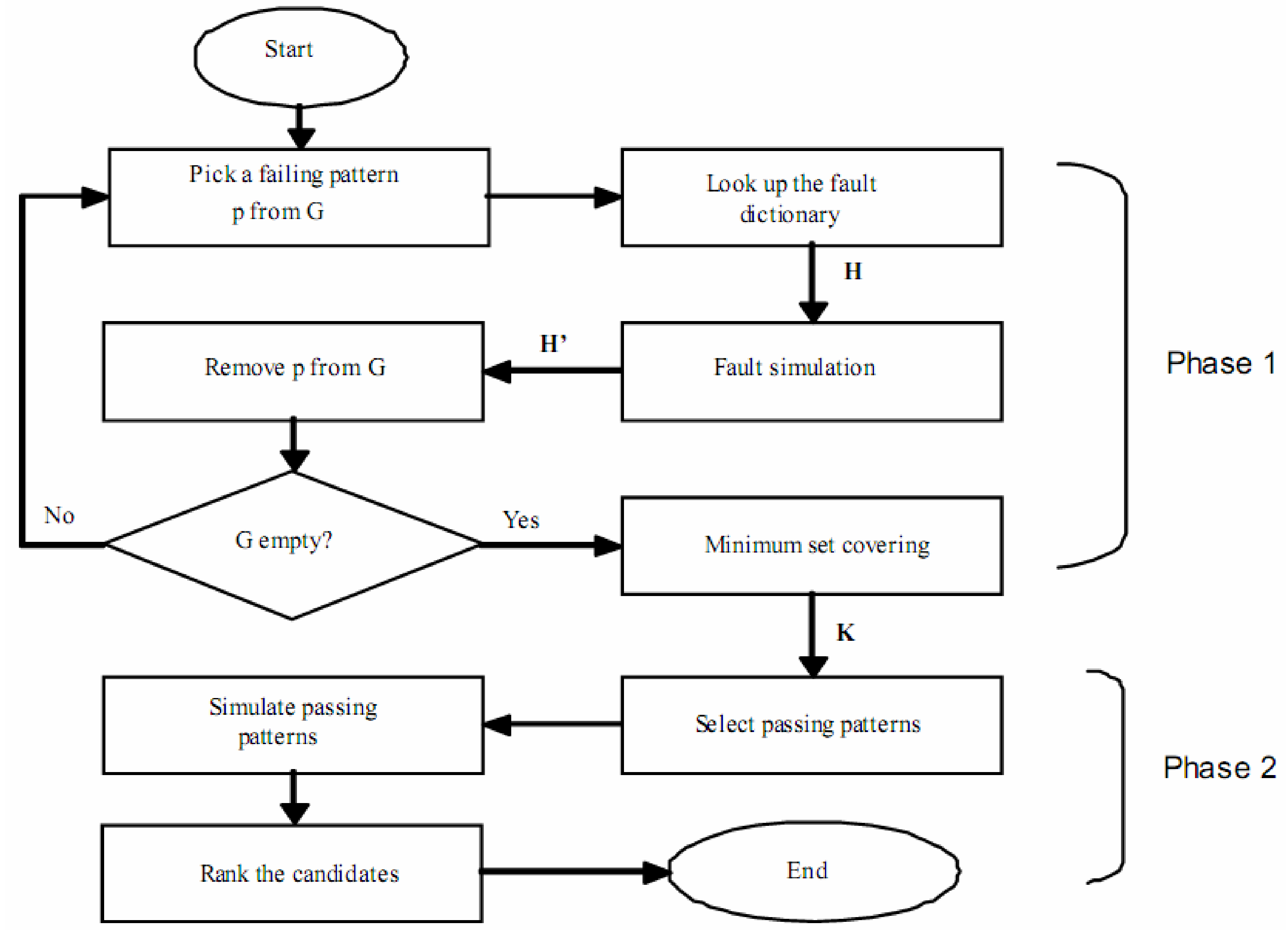
C: number of clocks in the circuit

Speeding Up the Effect-Cause Diagnosis

- Obtain the initial list of candidate faults using the small dictionary instead of back tracing.

1. For each failing pattern **p,** compress the failure data with a 32 bit MISR to get a compressed signature **R**
2. Search the dictionary we created to find a set **H** of candidates whose unique compressed signatures contain **R.**
3. **H** is then simulated to get a subset of candidates H' which is equal to Q'

Speeding Up the Effect-Cause Diagnosis



Start

Pick a failing pattern p from G

Look up the fault dictionary

H

Fault simulation

H’

Remove p from G

G empty?

No

Yes

Minimum set covering

Phase 1

K

Select passing patterns

Simulate passing patterns

Rank the candidates

End

Phase 2

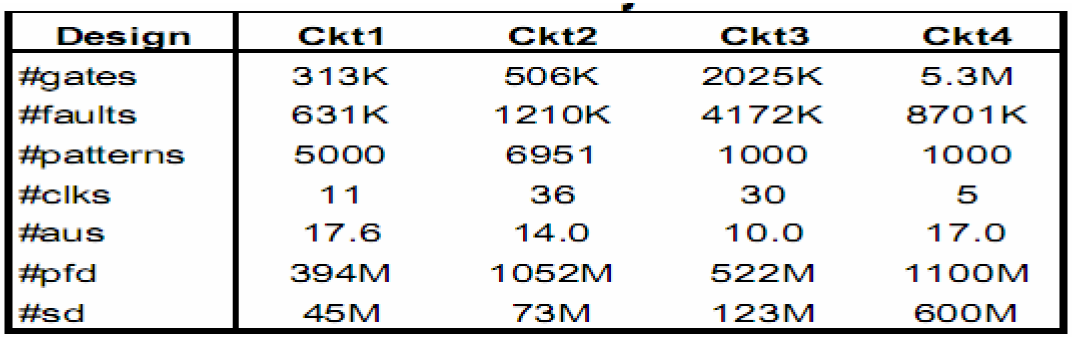
Reasons for Speed-Up

1. Backward path tracing is not used to determine the initial set of candidates

2. The numbers of events triggered by the faults in the initial set of candidates H is typically much smaller than that in the initial set of candidates Q obtained in the standard diagnosis procedures

Experimantal Results

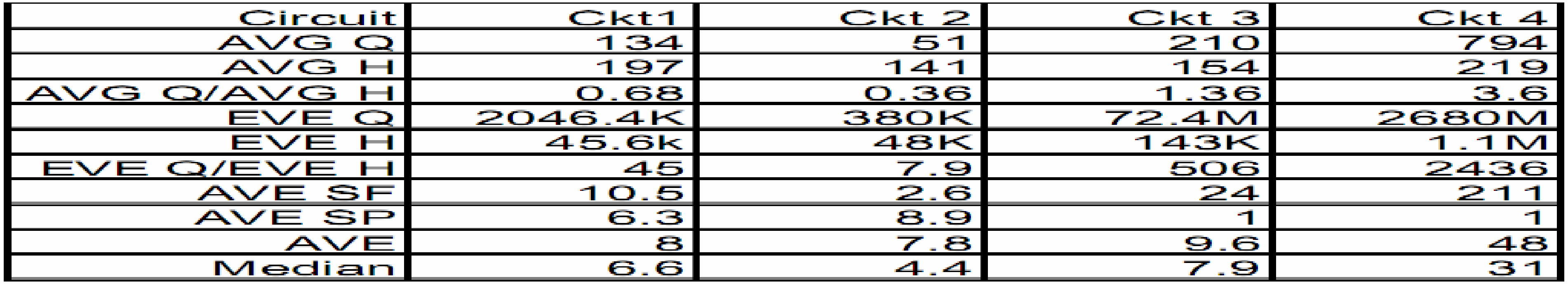
- The size of the proposed dictionary is considerably smaller than of a pass/fail dictionary



Design	Ckt1	Ckt2	Ckt3	Ckt4
#gates	313K	506K	2025K	5.3M
#faults	631K	1210K	4172K	8701K
#patterns	5000	6951	1000	1000
#clks	11	36	30	5
#aus	17.6	14.0	10.0	17.0
#pfd	394M	1052M	522M	1100M
#sd	45M	73M	123M	600M

- #aus: average number of unique signatures
- #pfd: size of pass/fail dictionary
- #sd: size of the proposed dictionary

Experimental Results



Circuit	Ckt1	Ckt 2	Ckt 3	Ckt 4
AVG Q	134	51	210	794
AVG H	197	141	154	219
AVG Q/AVG H	0.68	0.36	1.36	3.6
EVE Q	2046.4K	380K	72.4M	2680M
EVE H	45.6k	48K	143K	1.1M
EVE Q/EVE H	45	7.9	506	2436
AVE SF	10.5	2.6	24	211
AVE SP	6.3	8.9	1	1
AVE	8	7.8	9.6	48
Median	6.6	4.4	7.9	31

- AVG Q: average number of faults in Q for all test vectors
- AVG H: average number of faults in H for all test vectors
- EVE Q: average number of events triggered by faults in Q
- EVE H: average number of events triggered by faults in H
- AVE SF: average speed-up of phase 1
- AVE SP: average speed-up of phase 2
- AVE: average speed-up factor of the complete diagnostic procedure

QUESTIONS?