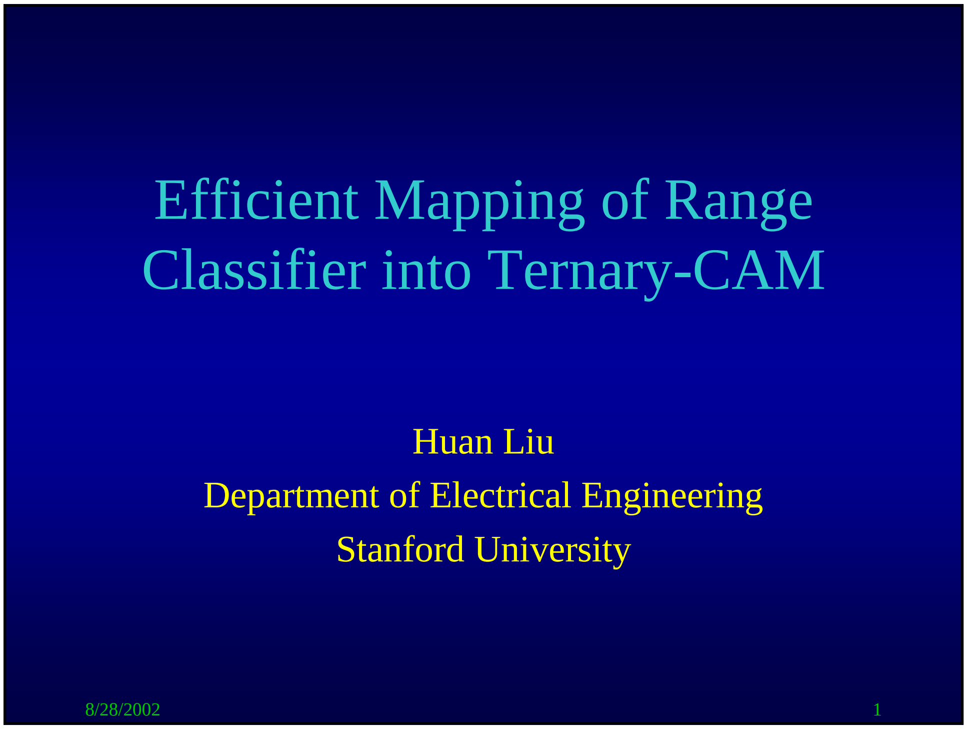

Efficient Mapping of Range Classifier into Ternary-CAM

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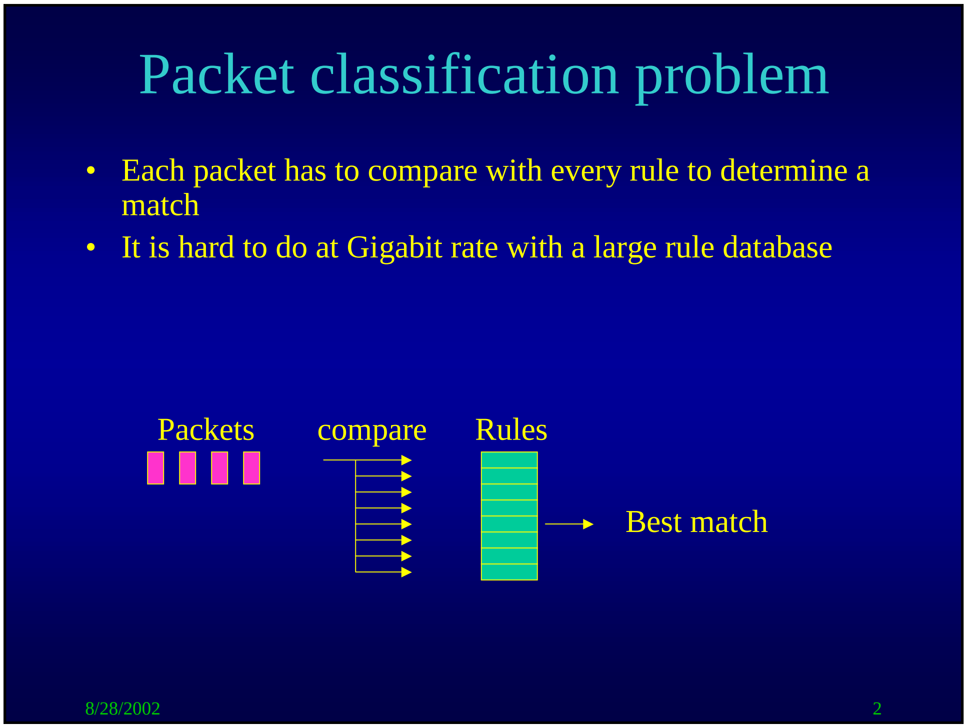
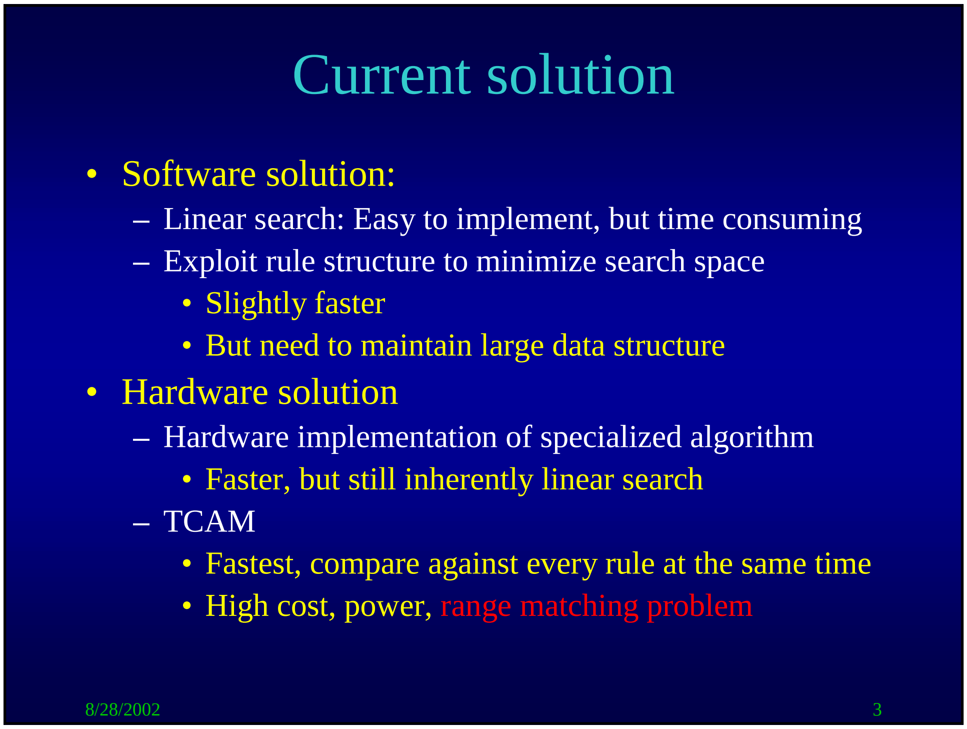


Packet classification problem

- Each packet has to compare with every rule to determine a match
- It is hard to do at Gigabit rate with a large rule database

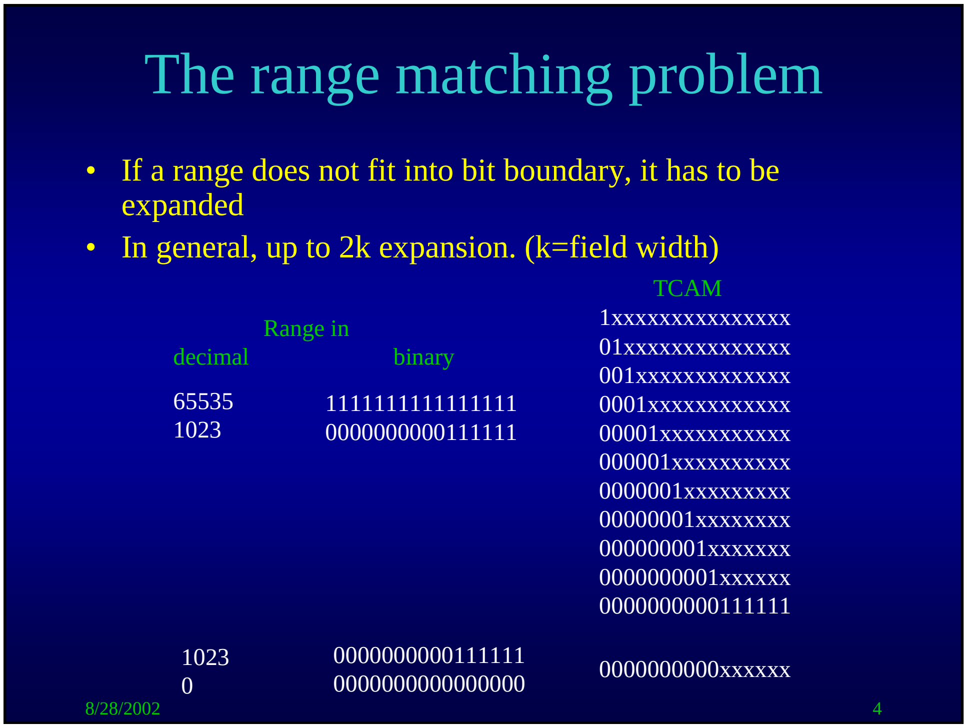
Packets compare Rules

Best match



Current solution

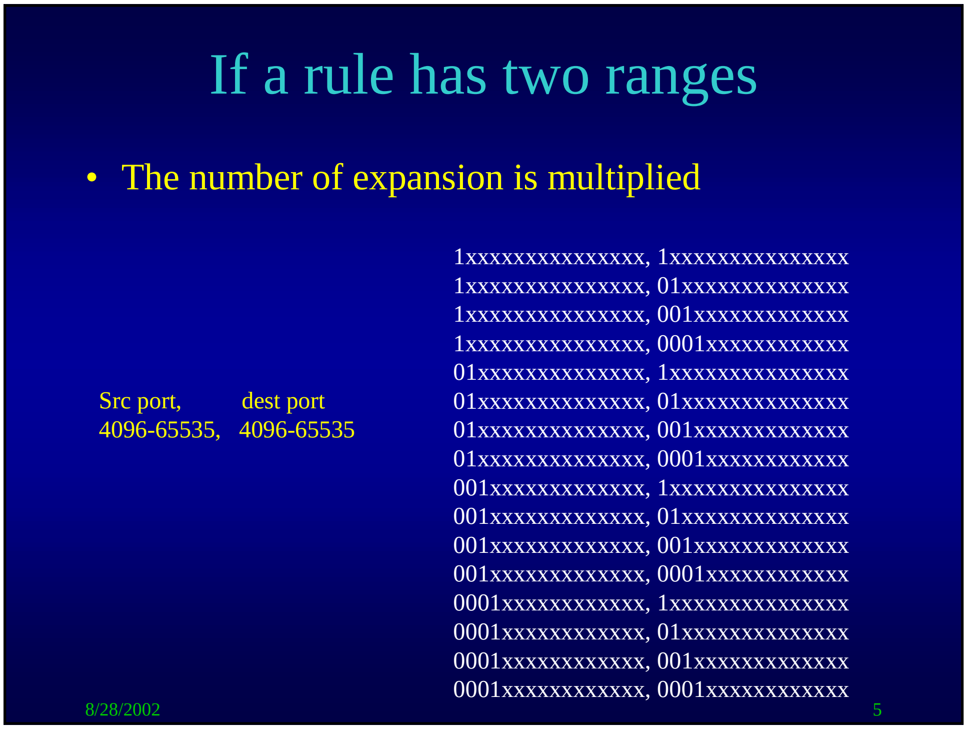
- Software solution:
  - Linear search: Easy to implement, but time consuming
  - Exploit rule structure to minimize search space
    - Slightly faster
    - But need to maintain large data structure
- Hardware solution
  - Hardware implementation of specialized algorithm
    - Faster, but still inherently linear search
  - TCAM
    - Fastest, compare against every rule at the same time
    - High cost, power, range matching problem



The range matching problem

- If a range does not fit into bit boundary, it has to be expanded
- In general, up to 2k expansion. (k=field width)

Range in decimal	binary	TCAM
65535 1023	1111111111111111 0000000000111111	1xxxxxxxxxxxxxxx 01xxxxxxxxxxxxxx 001xxxxxxxxxxxxx 0001xxxxxxxxxxxx 00001xxxxxxxxxxx 000001xxxxxxxxxx 0000001xxxxxxxxx 00000001xxxxxxxx 000000001xxxxxxx 0000000001xxxxxx 0000000000111111
1023 0	0000000000111111 0000000000000000	0000000000xxxxxx



If a rule has two ranges

- The number of expansion is multiplied

Src port, dest port
4096-65535, 4096-65535

```
1xxxxxxxxxxxxxxx, 1xxxxxxxxxxxxxxx
1xxxxxxxxxxxxxxx, 01xxxxxxxxxxxxxx
1xxxxxxxxxxxxxxx, 001xxxxxxxxxxxxx
1xxxxxxxxxxxxxxx, 0001xxxxxxxxxxxx
01xxxxxxxxxxxxxx, 1xxxxxxxxxxxxxxx
01xxxxxxxxxxxxxx, 01xxxxxxxxxxxxxx
01xxxxxxxxxxxxxx, 001xxxxxxxxxxxxx
01xxxxxxxxxxxxxx, 0001xxxxxxxxxxxx
001xxxxxxxxxxxxx, 1xxxxxxxxxxxxxxx
001xxxxxxxxxxxxx, 01xxxxxxxxxxxxxx
001xxxxxxxxxxxxx, 001xxxxxxxxxxxxx
001xxxxxxxxxxxxx, 0001xxxxxxxxxxxx
0001xxxxxxxxxxxx, 1xxxxxxxxxxxxxxx
0001xxxxxxxxxxxx, 01xxxxxxxxxxxxxx
0001xxxxxxxxxxxx, 001xxxxxxxxxxxxx
0001xxxxxxxxxxxx, 0001xxxxxxxxxxxx
```

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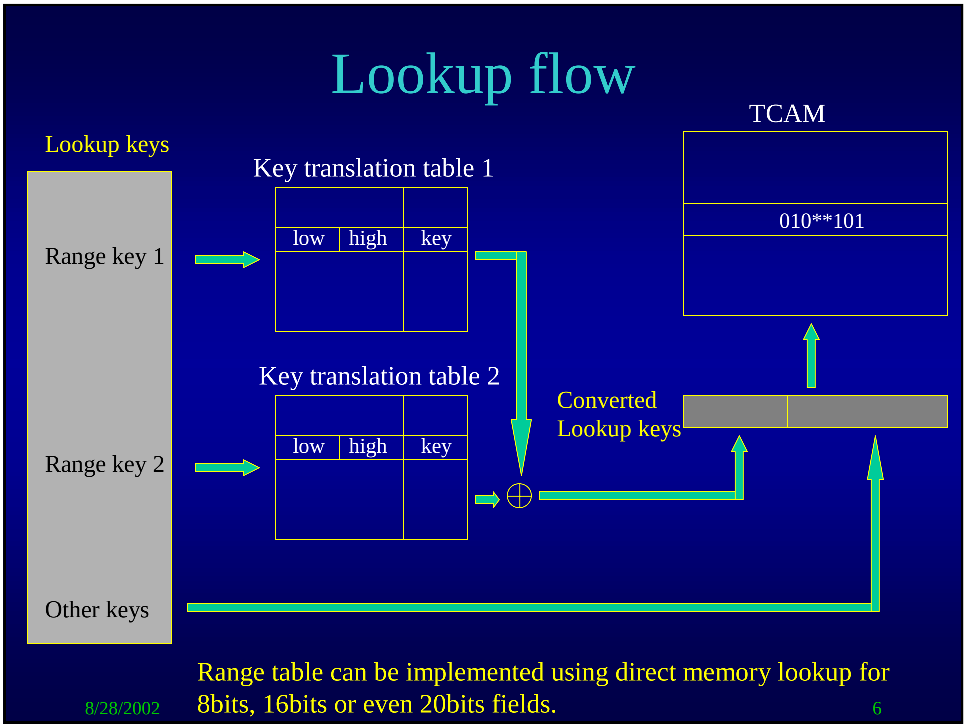

Lookup flow

Range table can be implemented using direct memory lookup for 8bits, 16bits or even 20bits fields.

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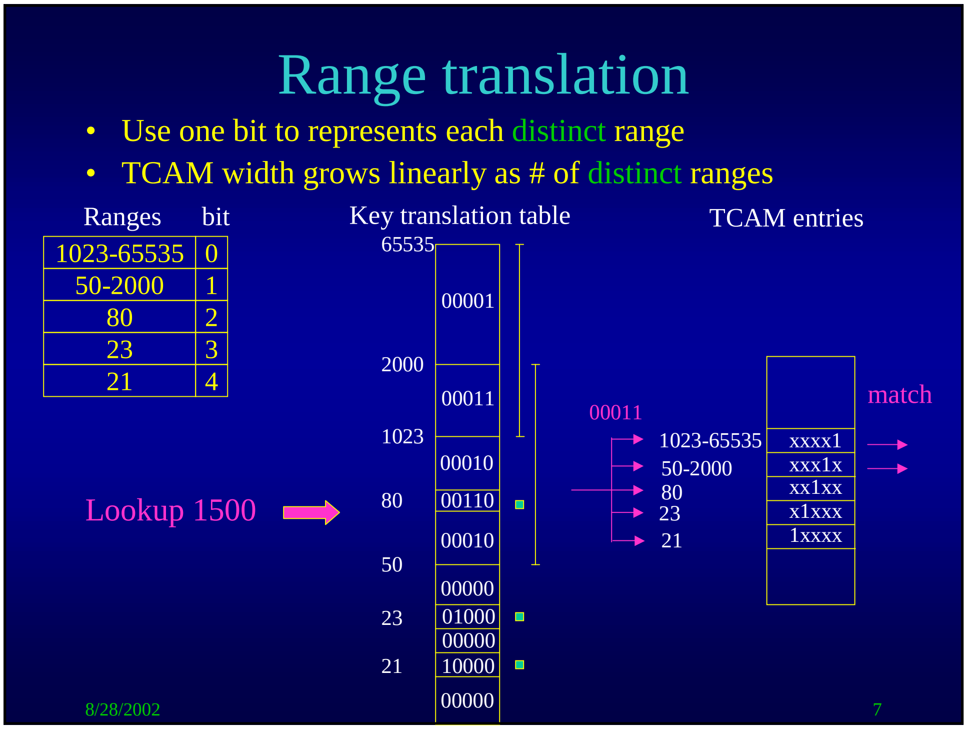

Range translation

- Use one bit to represents each distinct range
- TCAM width grows linearly as # of distinct ranges

Ranges	bit
1023-65535	0
50-2000	1
80	2
23	3
21	4

Key translation table

65535
00001
2000
00011
1023
00010
80
00110
00010
50
00000
23
01000
00000
21
10000
00000

Lookup 1500

00011

1023-65535
50-2000
80
23
21

TCAM entries

xxxx1
xxx1x
xx1xx
x1xxx
1xxxx

match

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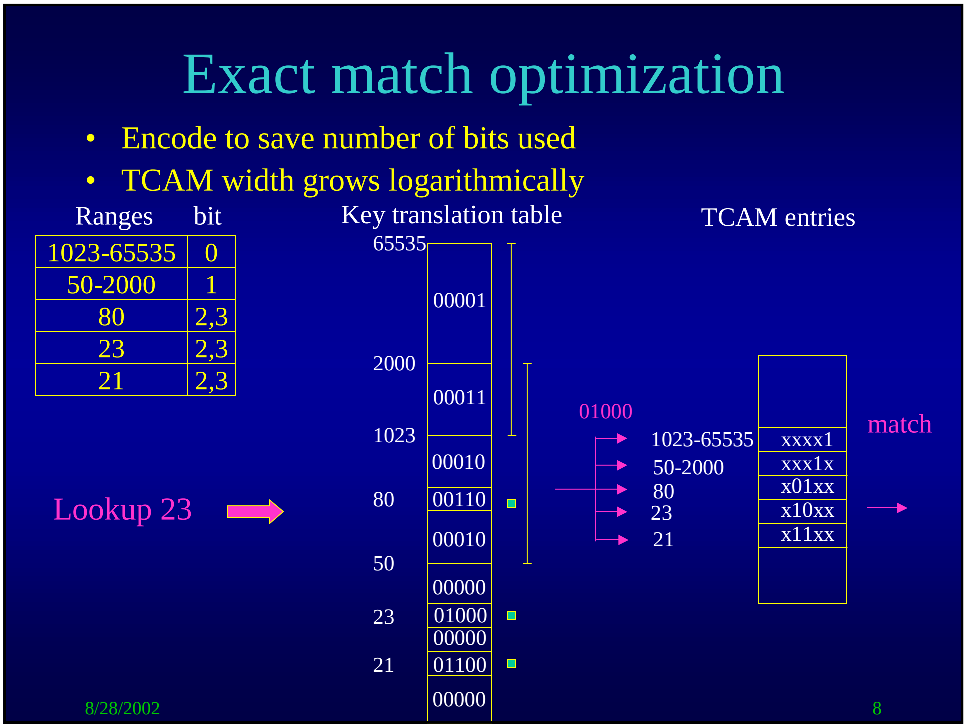

Exact match optimization

- Encode to save number of bits used
- TCAM width grows logarithmically

Ranges	bit
1023-65535	0
50-2000	1
80	2,3
23	2,3
21	2,3

Key translation table

65535
00001
2000
00011
1023
00010
80
00110
00010
50
00000
23
01000
00000
21
01100
00000

Lookup 23

01000

1023-65535
50-2000
80
23
21

TCAM entries

xxxx1
xxx1x
x01xx
x10xx
x11xx

match

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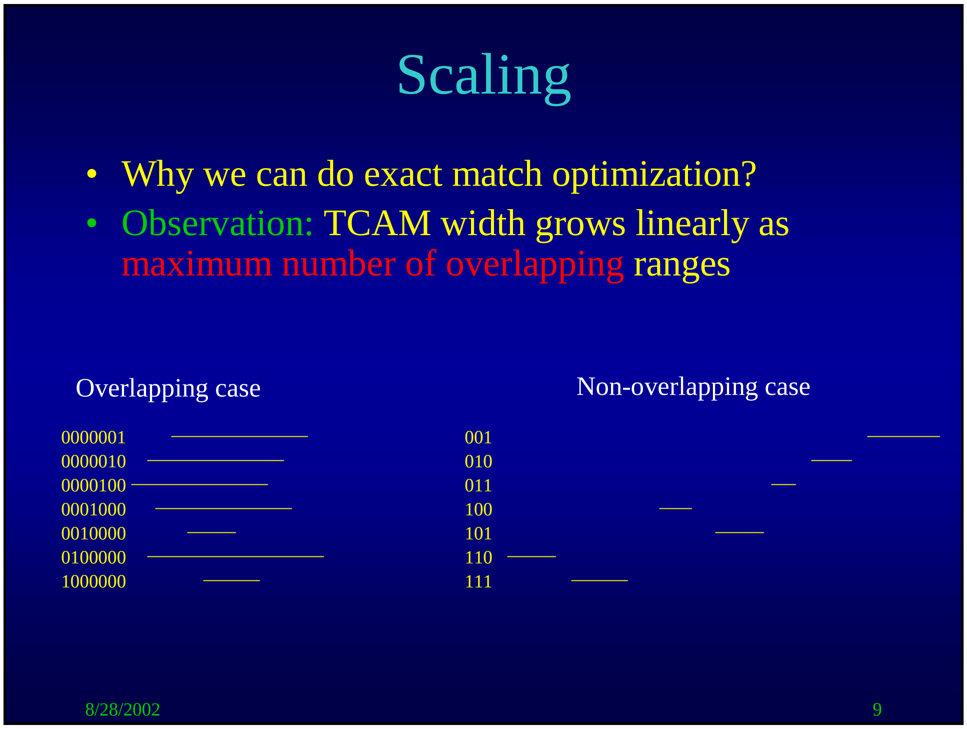


Scaling

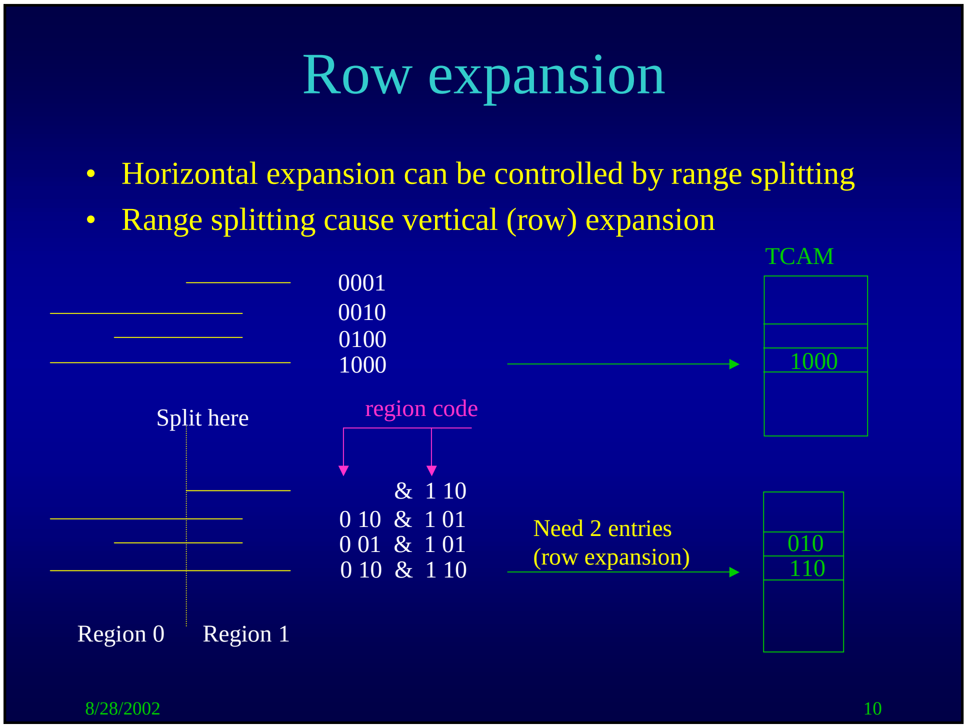
- Why we can do exact match optimization?
- Observation: TCAM width grows linearly as maximum number of overlapping ranges

Overlapping case

0000001
0000010
0000100
0001000
0010000
0100000
1000000

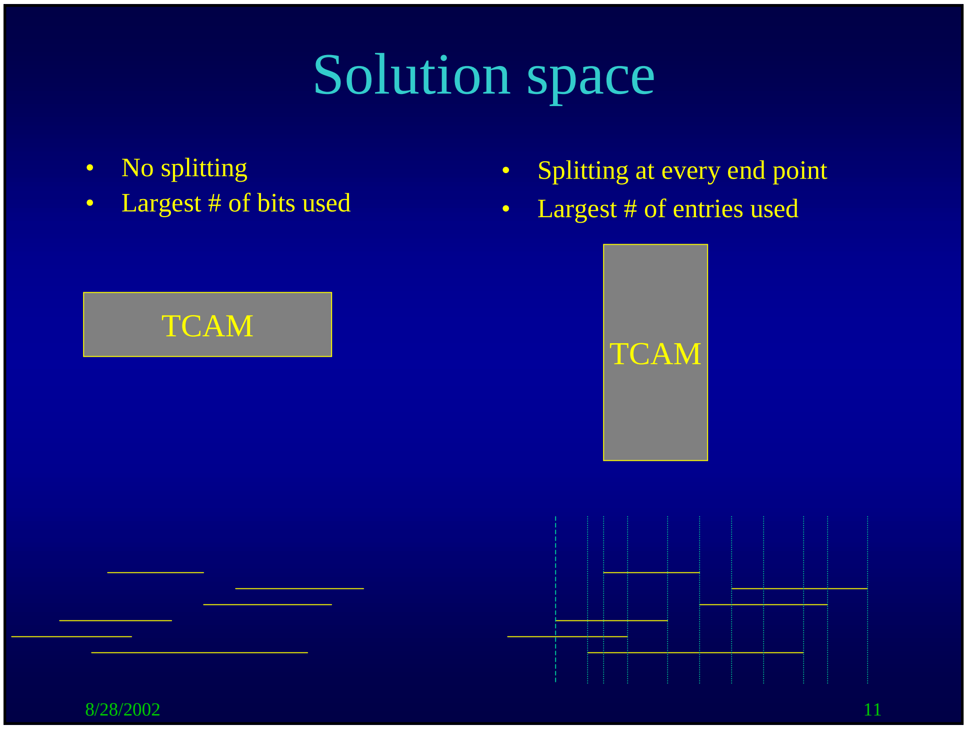
Non-overlapping case

001
010
011
100
101
110
111



Row expansion

- Horizontal expansion can be controlled by range splitting
- Range splitting cause vertical (row) expansion



Solution space

- No splitting
- Largest # of bits used

- Splitting at every end point
- Largest # of entries used

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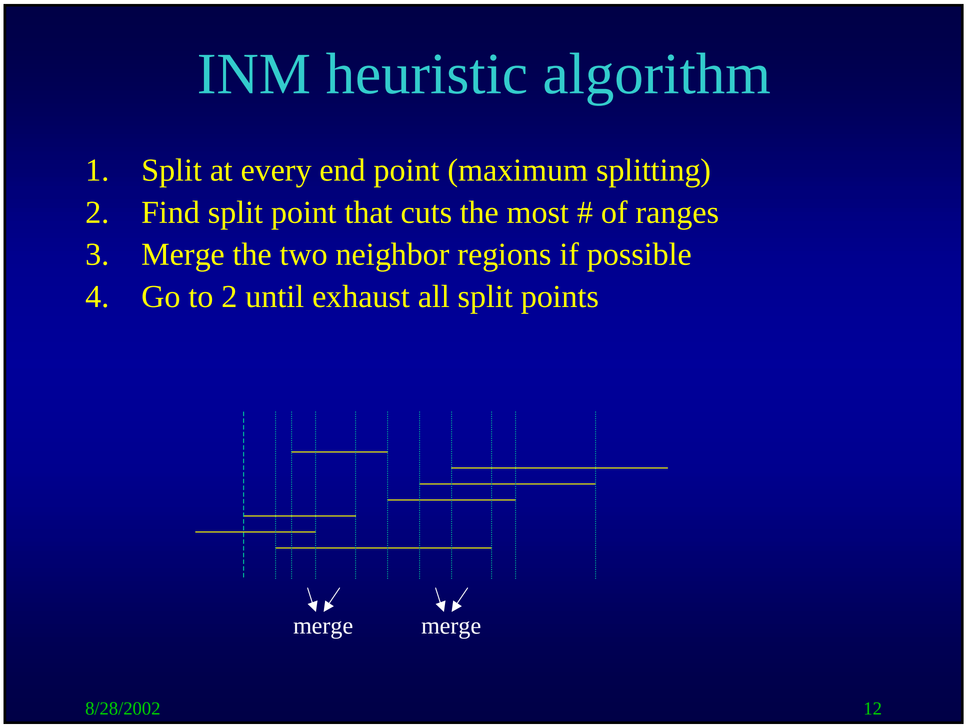

INM heuristic algorithm

1. Split at every end point (maximum splitting)
2. Find split point that cuts the most # of ranges
3. Merge the two neighbor regions if possible
4. Go to 2 until exhaust all split points

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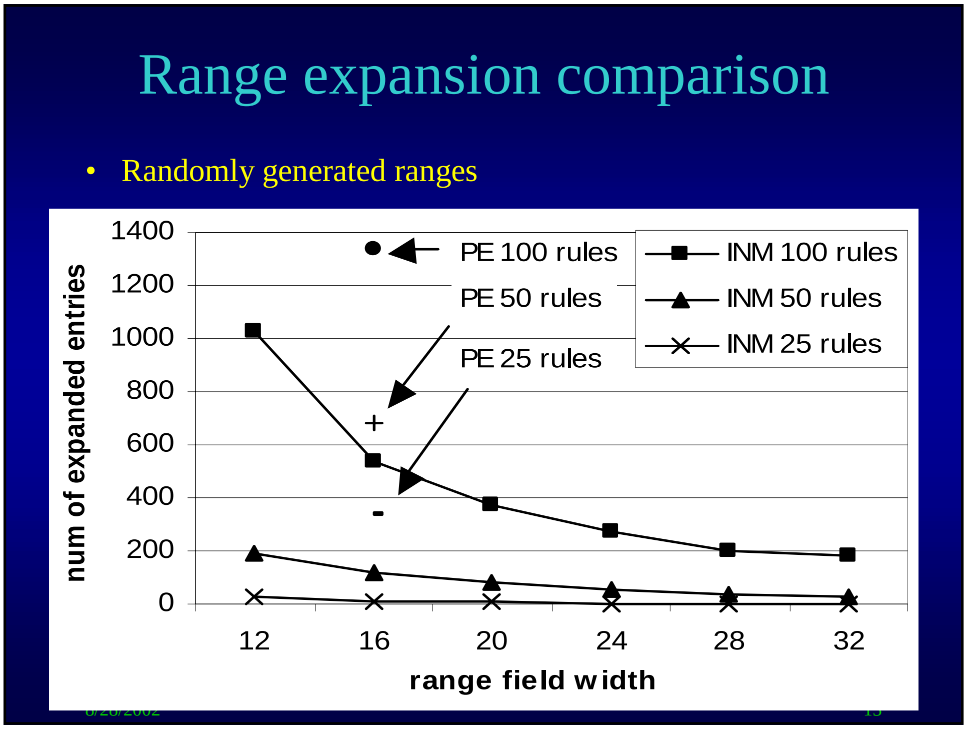

Range expansion comparison

- Randomly generated ranges

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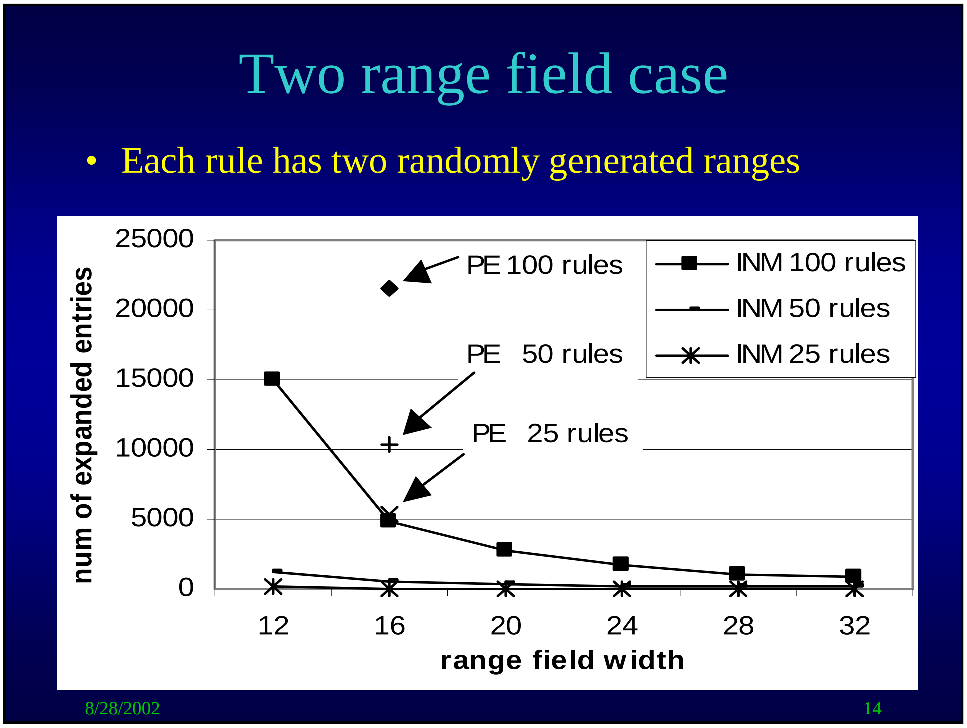

Two range field case

- Each rule has two randomly generated ranges

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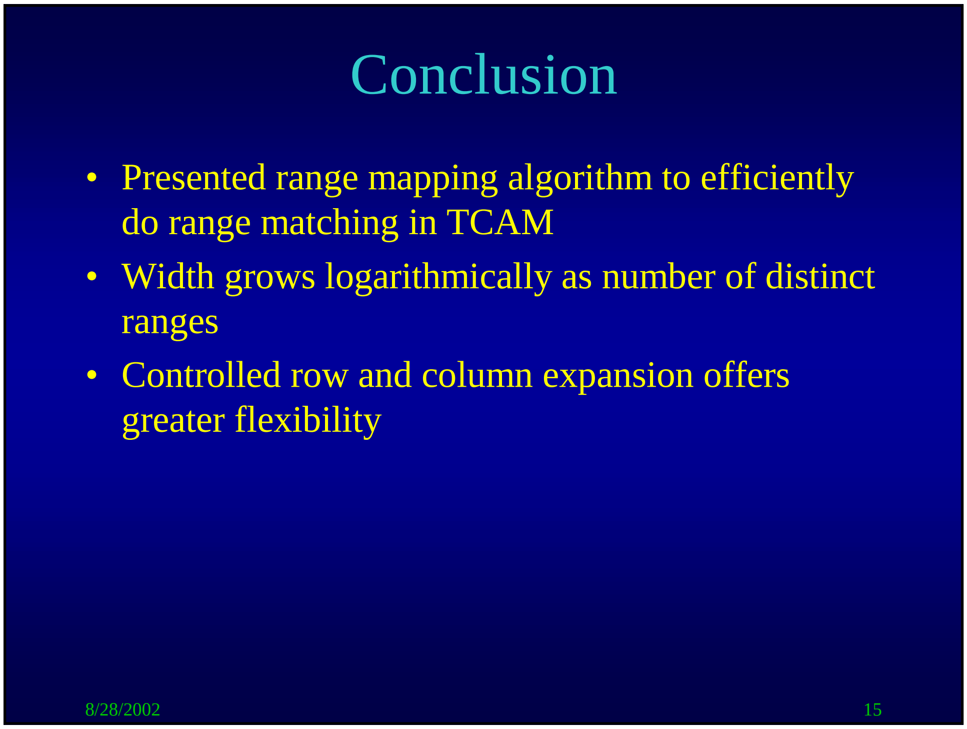

Conclusion

- Presented range mapping algorithm to efficiently do range matching in TCAM
- Width grows logarithmically as number of distinct ranges
- Controlled row and column expansion offers greater flexibility