Indexing Boolean Expressions

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Problem

- Ad Example
  - BE: age $\in$ {10,20} & country $\notin$ {US}
  - S: age=20 & country=FR & gender=F

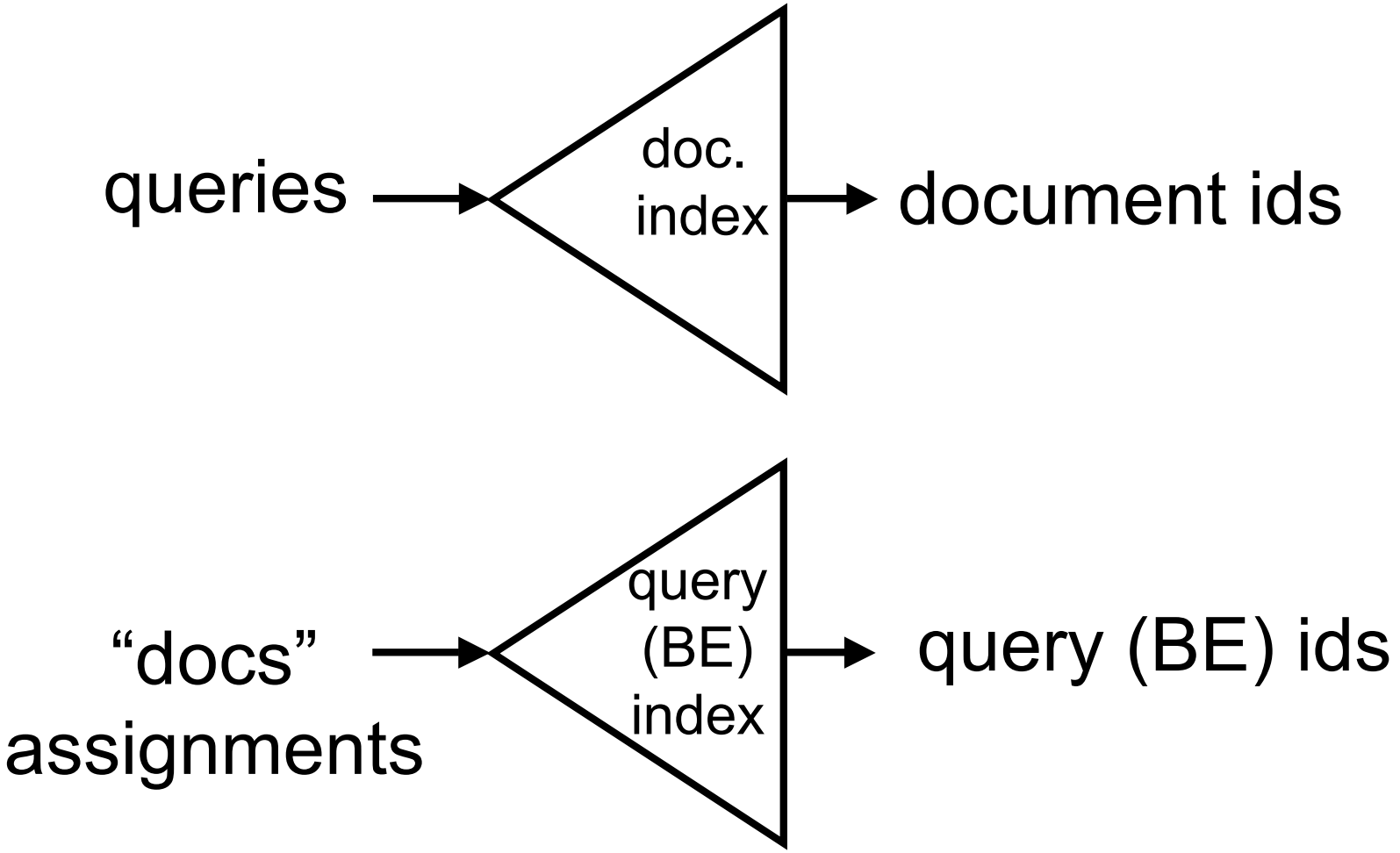
Problem

- Ad Example
  - BE: age $\in$ {10,20} & country $\notin$ {US}
  - S: age=20 & country=FR & gender=F
- Given an assignment S, find all matching boolean expressions (BEs)

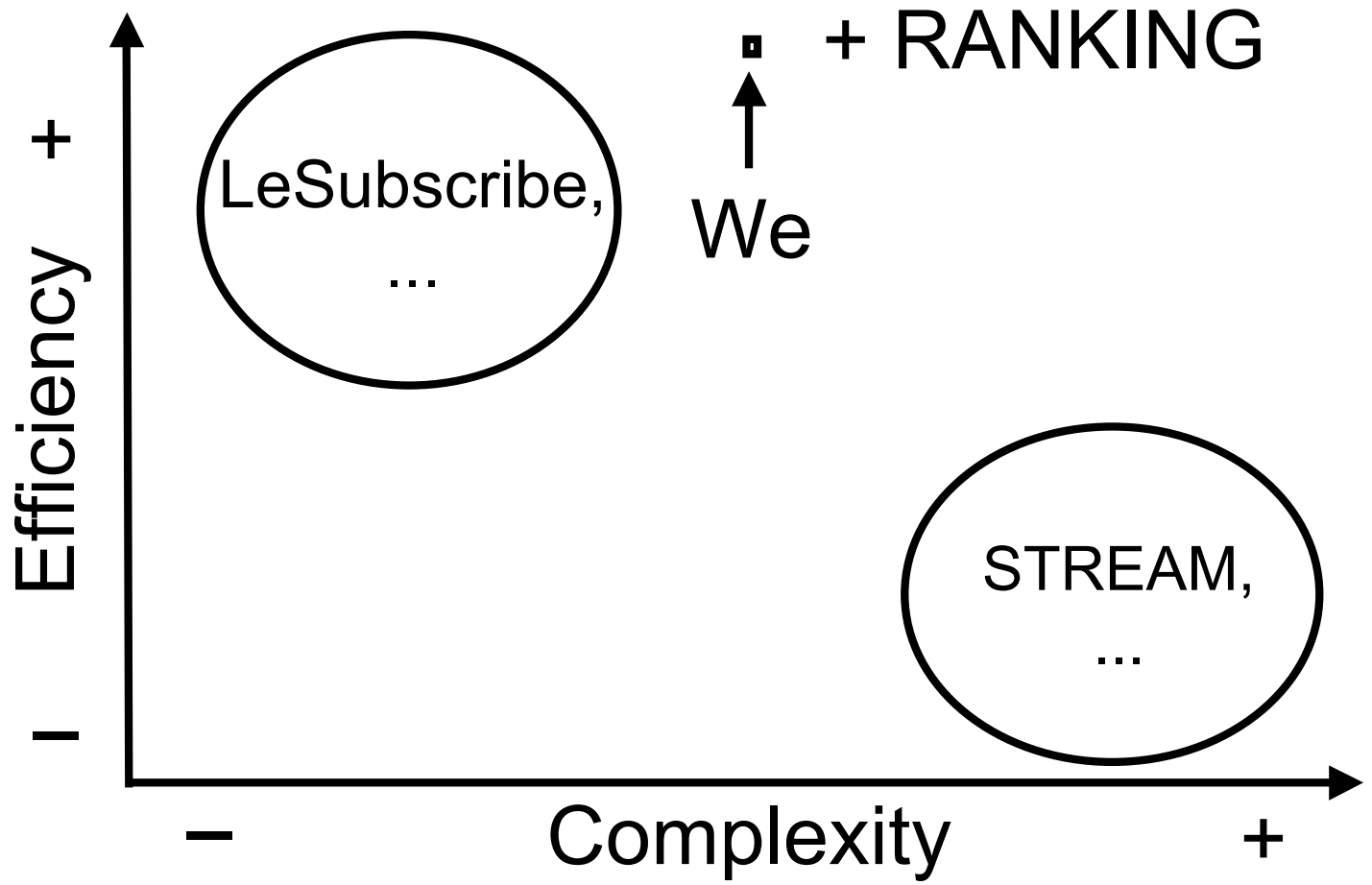
Possible applications

- Display advertising
- Publish/subscribe systems

Inverted index



Related works



Contributions

- Use inverted indexing techniques for "complex" BEs
  - DNF, CNF expressions of $\in$, $\notin$ predicates with multiple values
- Support top-k pruning given relevance scores

Outline

- Inverted index construction 
- Search algorithms
  - Conjunction (∈ only)
  - DNF
  - CNF (∈ only)
- Experimental results

Inverted index

E1: A ∈ {1}

E2: A ∈ {1} & B ∈ {2} & C ∈ {3,4}

Key	Posting List
(A,1)	E1, E2
(B,2)	E2
(C,3)	E2
(C,4)	E2

Inverted index

E1: A ∈ {1}

E2: A ∈ {1} & B ∈ {2} & C ∈ {3,4}

S: A=1 & B=2

Key	Posting List
(A,1)	E1, E2
(B,2)	E2
(C,3)	E2
(C,4)	E2

Posting Lists Used

Inverted index

- Conventional posting list operations (intersection, union) do not work correctly

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Conjunction algorithm (∈ only)

S: A=1 & B=2 & C=3 & D=4

K=3

Key	Posting List
(A,1)	E1, E2, E3
(B,2)	E2, E3
(C,3)	E3, E4
(D,4)	E4

Matching conjunctions of size K: {}

Conjunction algorithm (∈ only)

S: A=1 & B=2 & C=3 & D=4

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(A,1)	E1, E2, E3
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(A,1)	E1, E2, E3
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(D,4)	E4

Matching conjunctions of size K: {E3}

Conjunction algorithm (∈ only)

S: A=1 & B=2 & C=3 & D=4

K=3

Key	Posting List
(A,1)	E1, E2, E3 (end of list)
(B,2)	E2, E3 (end of list)
(C,3)	E3, E4
(D,4)	E4

Matching conjunctions of size K: {E3}

Conjunction algorithm (∈ only)

S: A=1 & B=2 & C=3 & D=4

K=3

Key	Posting List
(C,3)	E3, E4
(D,4)	E4
(A,1)	E1, E2, E3 (end of list)
(B,2)	E2, E3 (end of list)

Matching conjunctions of size K: {E3}

Conjunction algorithm (∈ only)

S: A=1 & B=2 & C=3 & D=4

K=3

Key	Posting List
(C,3)	E3, E4 (end of list)
(D,4)	E4 (end of list)
(A,1)	E1, E2, E3 (end of list)
(B,2)	E2, E3 (end of list)

Matching conjunctions of size K: {E3}

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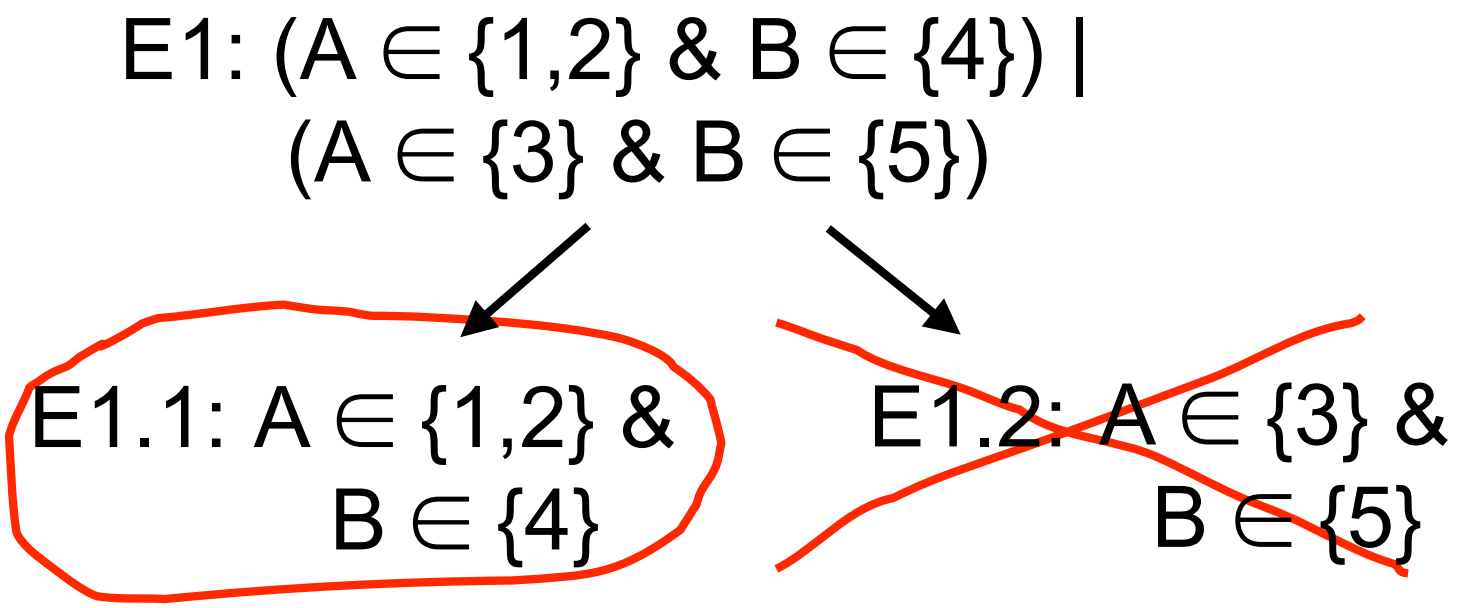
DNF algorithm

E1: (A ∈ {1,2} & B ∈ {4}) |
(A ∈ {3} & B ∈ {5})

E1.1: A ∈ {1,2} &
B ∈ {4}

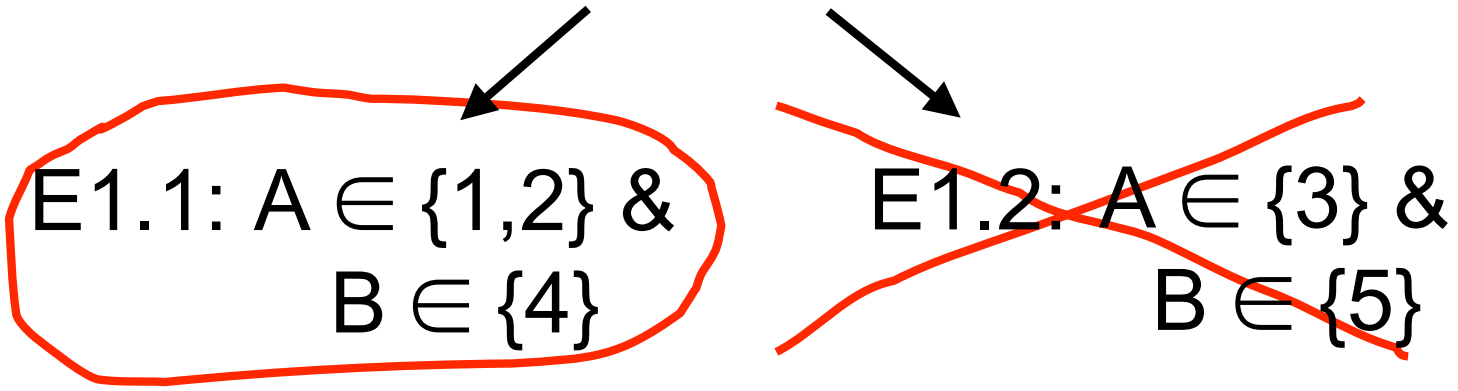
E1.2: A ∈ {3} &
B ∈ {5}

DNF algorithm



DNF algorithm

E1: (A ∈ {1,2} & B ∈ {4}) |
(A ∈ {3} & B ∈ {5})



E1 is satisfied

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CNF algorithm (∈ only)

- Similar to conjunction algorithm except:
  - Size of BE = # of disjunctions
  - Make sure all disjunctions of BE are satisfied using disjunction IDs

E1: $(A \in \{1\} \mid B \in \{2\}) \;\&\; (C \in \{3\} \mid D \in \{4\})$

disjunction 1 disjunction 2

More algorithms in paper

- Search algorithms for DNF/CNF BEs with $\notin$ predicates
- Top-k algorithms for DNF/CNF BEs based on relevance scores

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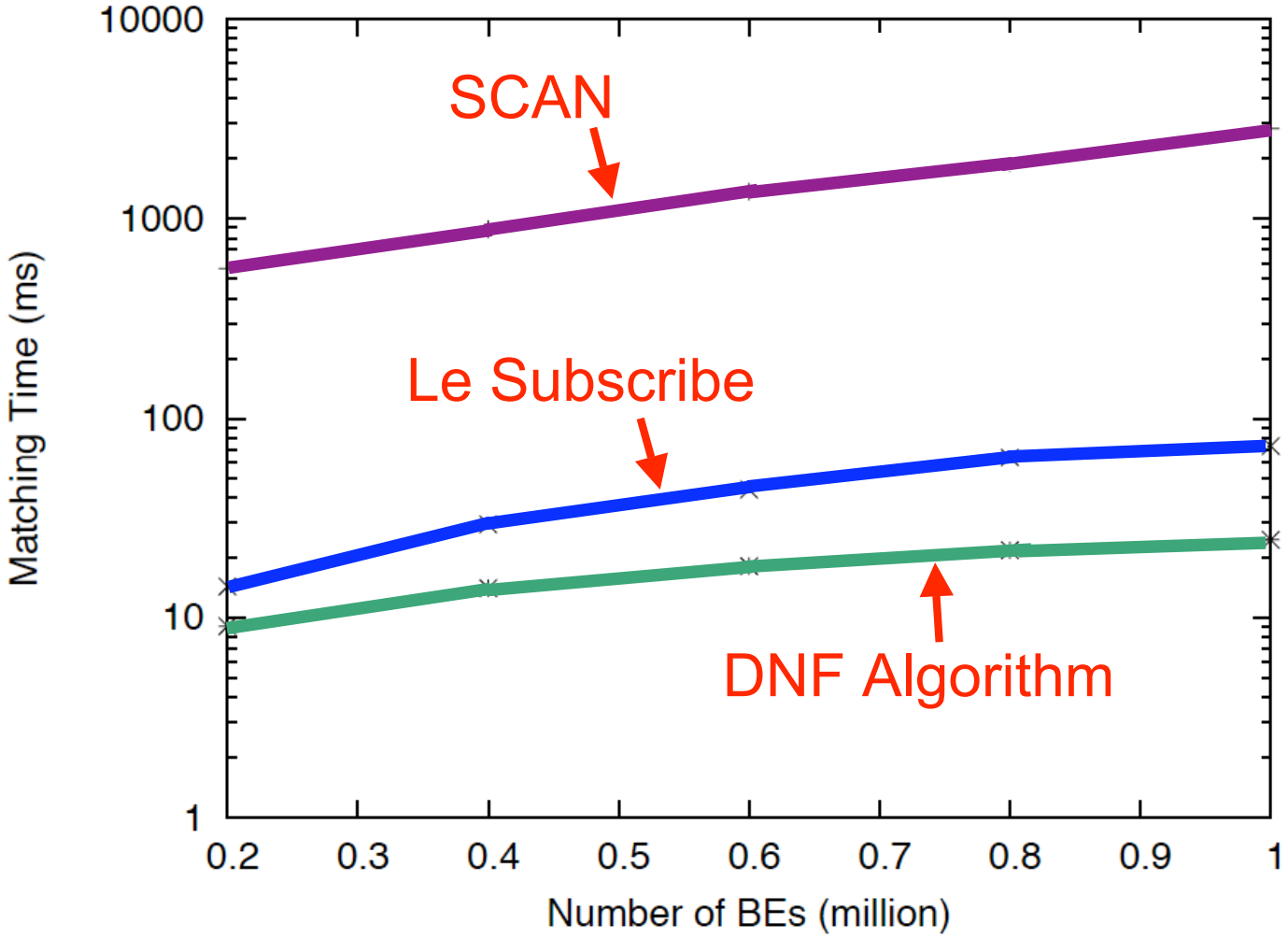
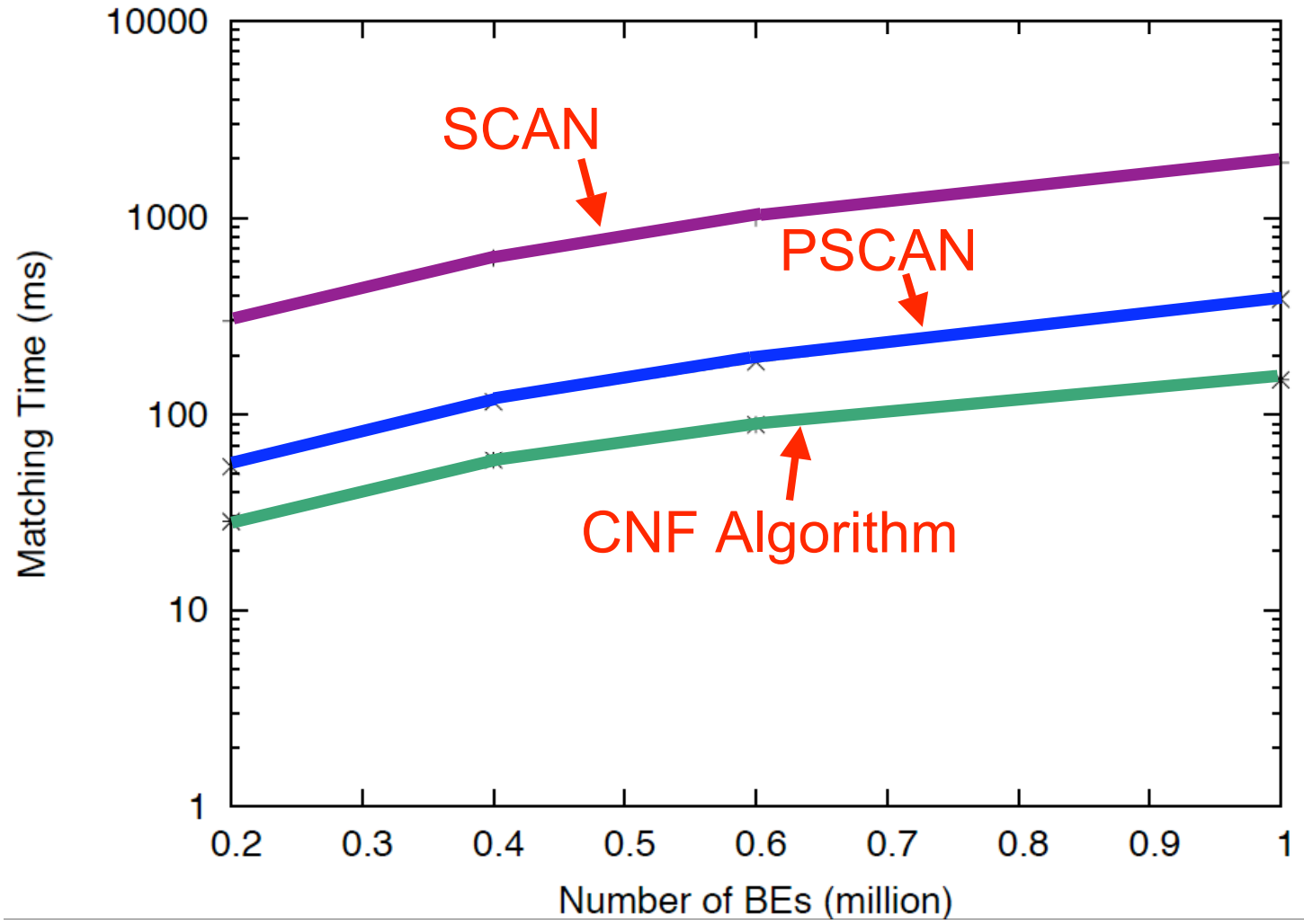
Data sets

- Assignments = Display advertising Impressions (Ad opportunities)
- BEs = Synthetic workloads generated from display advertising contracts
- Up to 1 million DNF/CNF BEs generated
- High dimensional (~1500)

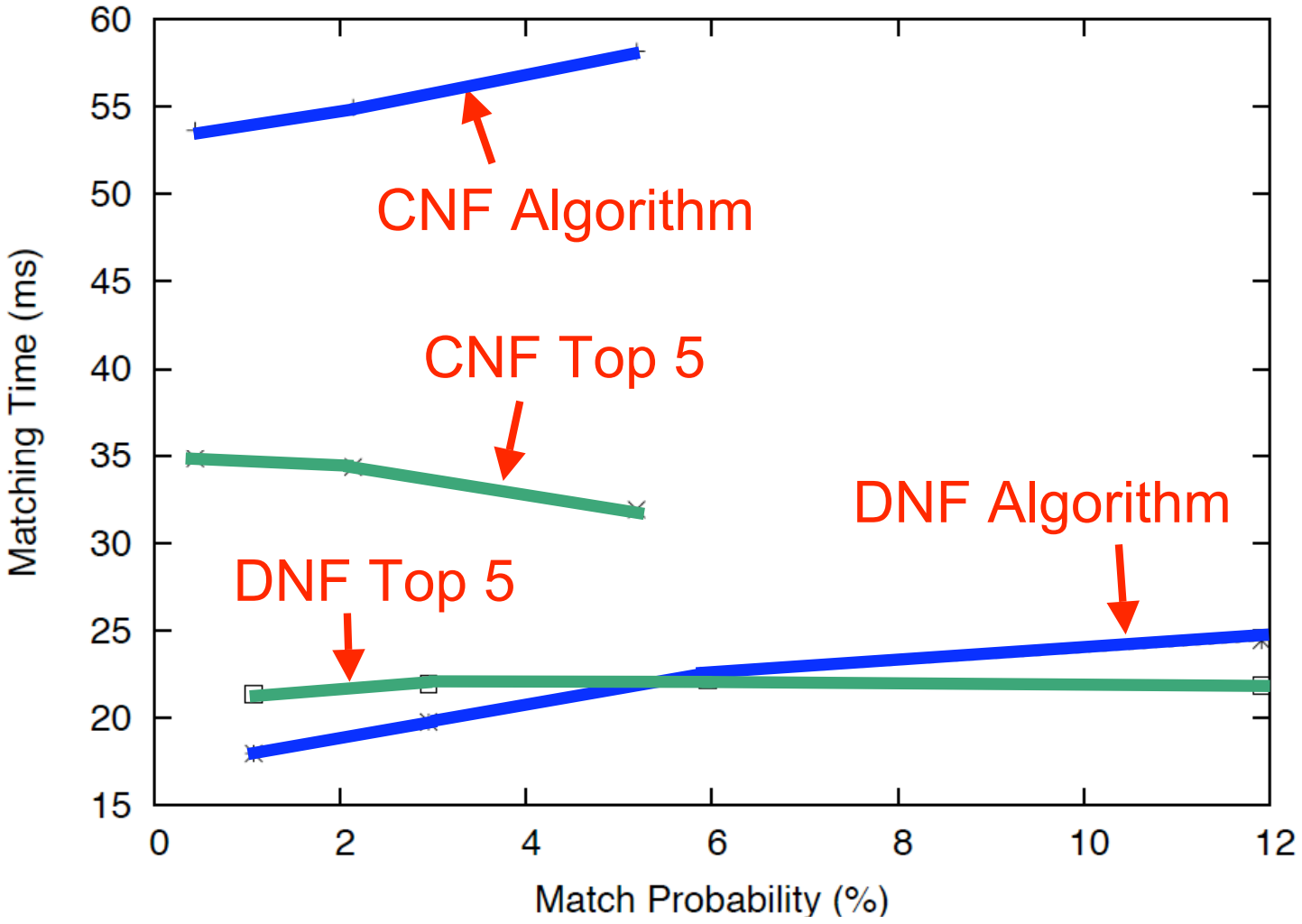
DNF algorithm scalability



CNF algorithm scalability



Top-k algorithms results



Conclusion

- Proposed algorithms that use inverted indexes to efficiently search matching DNF/CNF BEs
- Proposed top-k algorithms for BEs based on relevance scores