Parallel implementation of Apriori algorithm and association of mining rules using MPI

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CSE 633- Parallel Algorithms

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What is Apriori

- An efficient algorithm in data mining to find the undiscovered relationships between different items.
- Operates on databases containing a set of transactions with each transaction having a number of item sets.
- Aims to find the set of “frequent item-sets” and “association rules” between the items.

Frequent Item Sets

TID	*Items*
1	**Bread, Milk**
2	**Bread, Diaper, Beer, Eggs**
3	**Milk, Diaper, Beer, Coke**
4	**Bread, Milk, Diaper, Beer**
5	**Bread, Milk, Diaper, Coke**

- An item set is a collection of one or more items. Eg {Bread, Milk}
- Those items which occur more frequent.
- In other words, the item sets whose support is greater than the given support.

Support and Support Count

- Support Count is the number of transactions containing the itemsets. Eg – {Bread, Milk} = 3
- Support = Support Count/Total num of transactions eg – {Bread, Milk} = 3/5 =0.6
- Frequent Item sets are those whose support is greater than or equal to the specified support.
- It can be 1- itemset, 2-itemset… upto n-itemsets, where n, is the total number of items.

Association rules

- Association rules is used for discovering interesting relationships among the items.
- Confidence of an association rule X-> Y = (# of transactions of X U Y) /(# of transactions of X)
- An association rule is considered to be a strong association rule if its support and confidence are greater than the specified support and confidence.

Rule Generation

Suppose min_sup=0.3, min_conf=0.6,
Support({Beer, Diaper, Milk})=0.4

TID	*Items*
1	**Bread, Milk**
2	**Bread, Diaper, Beer, Eggs**
3	**Milk, Diaper, Beer, Coke**
4	**Bread, Milk, Diaper, Beer**
5	**Bread, Milk, Diaper, Coke**

All candidate rules:

{Beer} → {Diaper, Milk} (s=0.4, c=0.67)
{Diaper} → {Beer, Milk} (s=0.4, c=0.5)
{Milk} → {Beer, Diaper} (s=0.4, c=0.5)
{Beer, Diaper} → {Milk} (s=0.4, c=0.67)
{Beer, Milk} → {Diaper} (s=0.4, c=0.67)
{Diaper, Milk} → {Beer} (s=0.4, c=0.67)

All non-empty real subsets

{Beer} , {Diaper} , {Milk}, {Beer, Diaper}, {Beer, Milk} , {Diaper, Milk}

Strong rules:

{Beer} → {Diaper, Milk} (s=0.4, c=0.67)
{Beer, Diaper} → {Milk} (s=0.4, c=0.67)
{Beer, Milk} → {Diaper} (s=0.4, c=0.67)
{Diaper, Milk} → {Beer} (s=0.4, c=0.67)

The Apriori Algorithm

- C_k: Candidate itemset of size k
- L_k : frequent itemset of size k

- L_1 = {frequent items};
- for (k = 1; L_k !=∅; k++) do
  - *Candidate Generation:* C_{k+1} = candidates generated from L_k;
  - *Candidate Counting:* for each transaction *t* in database do increment the count of all candidates in C_{k+1} that are contained in *t*
  - L_{k+1} = candidates in C_{k+1} with min_sup
- return $\cup_k L_k$;

Candidate-generation: Self-joining

- Given L_k, how to generate C_{k+1}?

  Step 1: self-joining L_k

  INSERT INTO C_{k+1}

  SELECT $p.item_1, p.item_2, \ldots, p.item_k, q.item_k$

  FROM $L_k\ p, L_k\ q$

  WHERE $p.item_1 = q.item_1, \ldots, p.item_{k-1} = q.item_{k-1}, p.item_k < q.item_k$

- Example

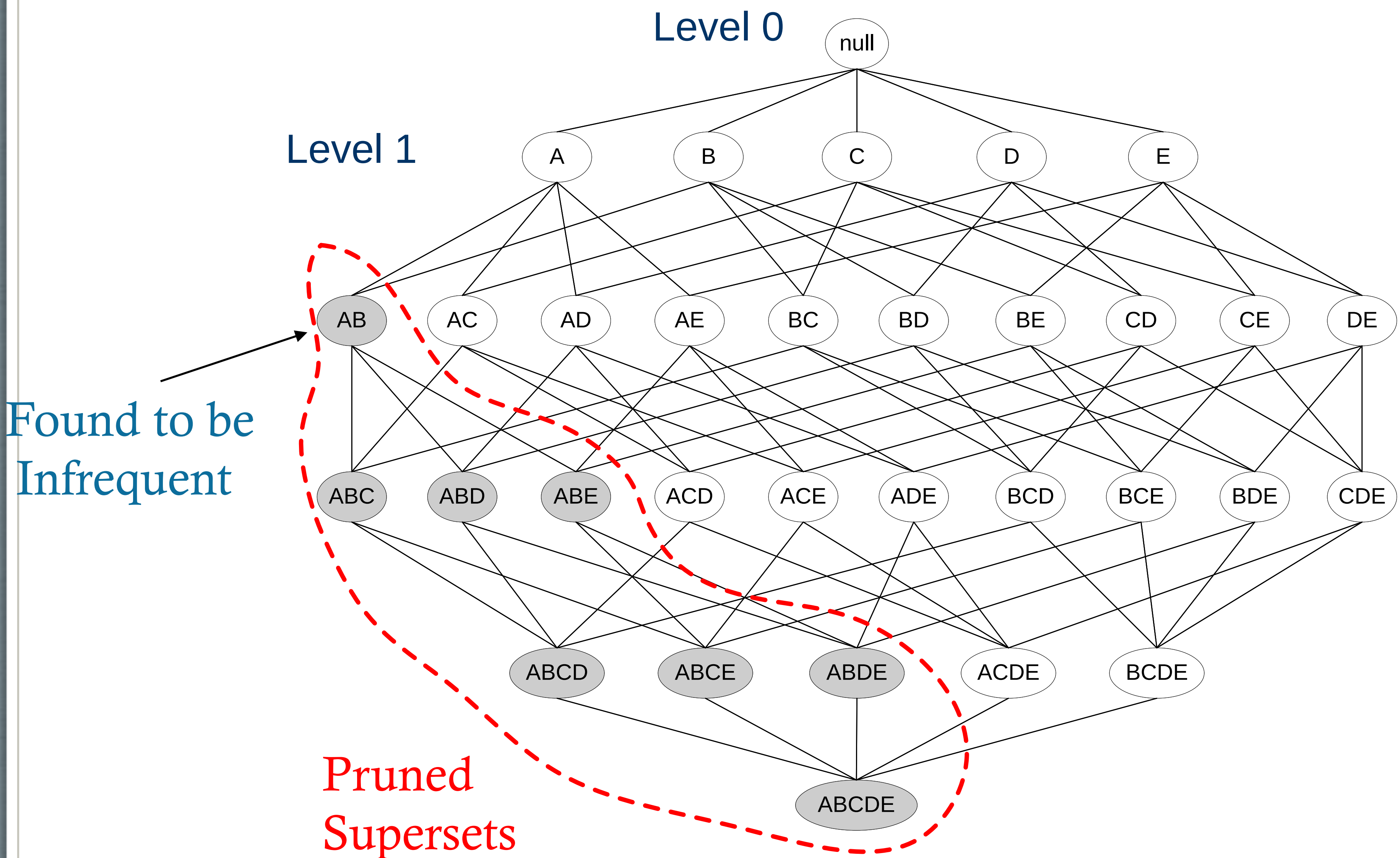
  $L_3 = \{abc, abd, acd, ace, bcd\}$

  Self-joining: $L_3 * L_3$

  - *abcd* ← *abc* * *abd*
  - *acde* ← *acd* * *ace*

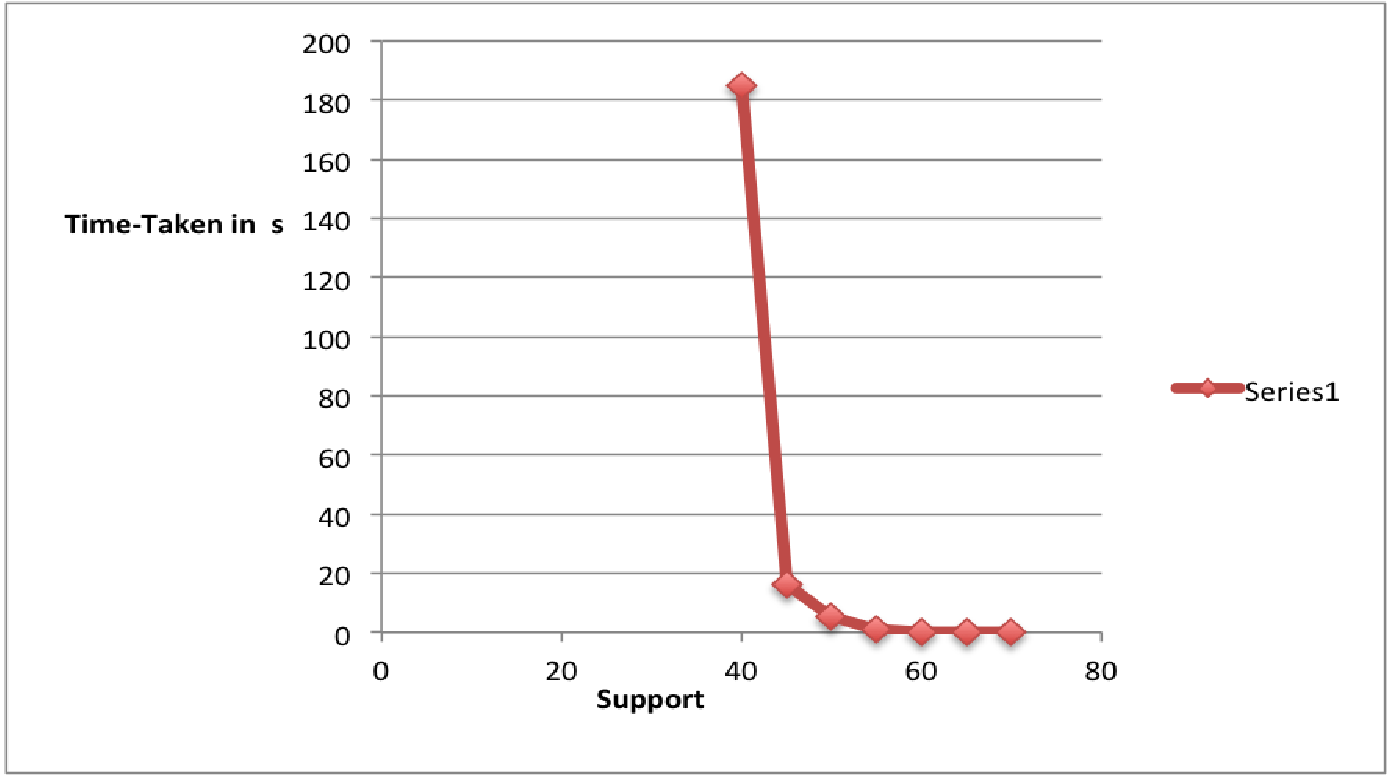
  $C_4 = \{abcd, acde\}$

Illustrating Apriori Principle



Output pattern of serial implementation

- Number of transactions = 100 and different items = 200



Interesting patterns in the output

- Output varies according to different inputs of support and confidence and number of item sets present.
- When the support is less, more time is taken to run the program.
- As support increases, the time taken to run the algorithm will be less and gradually comes to constant after a point.

Challenges of apriori algorithm

- More time is taken to generate output for low support values.
- To discover a frequent pattern of size 100, about 2^100 candidates needed to generate.
- Multiple scans of database
- Solution ???? – Parallelize it.

Parallel implementation

- Divide the data sets.
- Each processor P_i will have its on data set D_i
- Each processor P_i reads the values of the data set from a large flat file.
- Each processor do calculation of count of item sets in its own specific processing unit..

How it works

- Support and confidence are given as input to first processor.
- First processor will broadcast the support and confidence to every other processors.
- Each processor generates the first frequent item sets from the input data.
- Then data is divided between different processors.

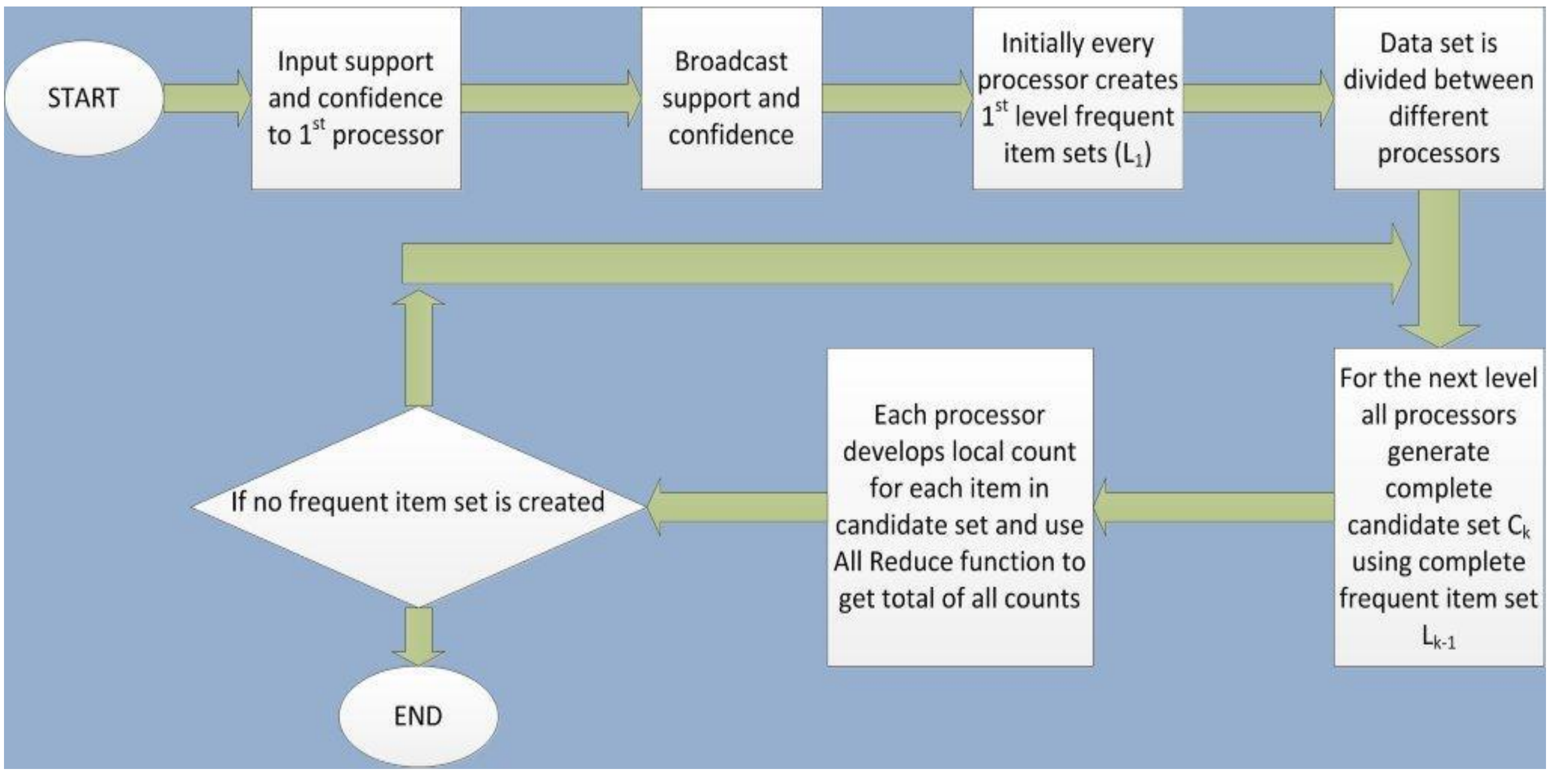
In subsequent passes

- Each processor P_i develops the complete C_k, using the complete frequent itemset L_{k-1} created at the end of pass k-1
- Processor P_i develop local support counts for candidates in C_k , using its local data partition.
- Then each processor P_i exchanges its local counts to master processor to develop the global C_k counts.

Continued….

- Each processor P_i then computes L_k from C_k.
- Each processor P_i independently makes the decision to terminate or continue to next pass.
- The decision will be identical as the processors have all identical L_k.

Flow chart of parallel implementation



Parallel rule generation

- Generating rules in parallel simply involves partitioning the set of frequent item sets among the processors.
- Each processor generates the rules using the below algorithm
- If a rule Bread, Milk, Coffee->Diaper does not satisfy the minimum confidence, then no need to consider rules like Bread, Milk-> Coffee, Diaper.

MPI Commands used

- MPI_Comm_rank
- MPI_Bcast
- MPI_AllReduce
- Language used – C++

Test Cases

- Case 1 – To find the output pattern for different values of support and constant number of transactions
- Case 2 – To find the output pattern for different number of transactions with same item sets.
- Case 3 – To find the output pattern for different item sets with same number of transactions.

CASE 1

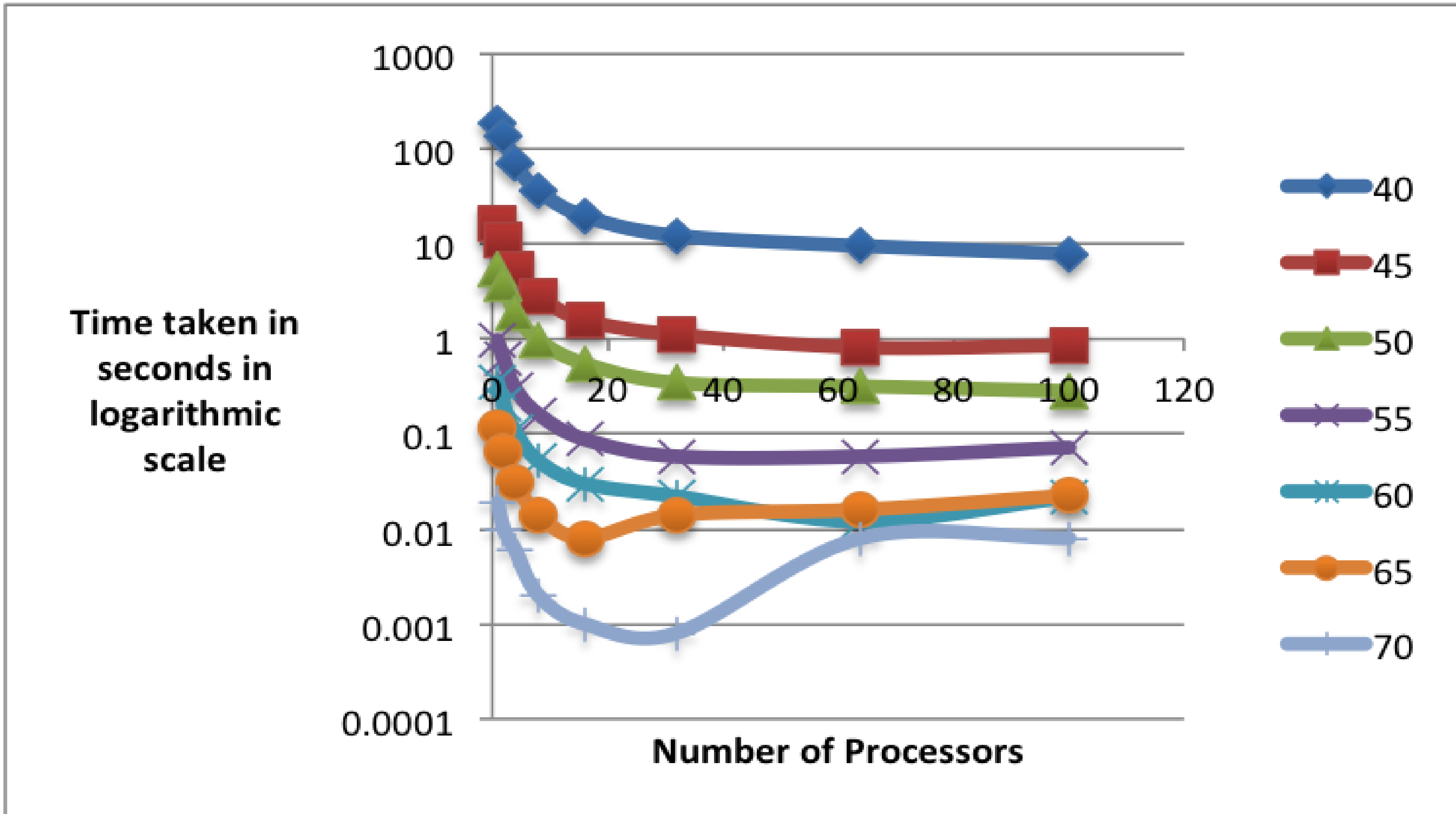
- Output value for different values of support.
- Both number of item sets and number of transactions are kept constant.
- Various values of support from 40 to 70 are tested.
- Confidence is also kept constant at 50.

Output of parallel implementation

- Number of transactions =100, different number of items = 200.
- Confidence = 50

	1	2	4	8	16	32	64	100	Freq. Items	Assn Elements
40	184.815	139.554	69.596	36.438	19.628	12.244	9.578	7.882	1077	2528
45	16.1468	10.968	5.42	2.856	1.576	1.11	0.816	0.752	424	614
50	5.5649	3.762	1.866	0.98	0.552	0.346	0.318	0.282	174	138
55	0.9734	0.602	0.3	0.162	0.088	0.058	0.058	0.072	64	16
60	0.345	0.204	0.106	0.052	0.03	0.022	0.012	0.0216	36	4
65	0.1175	0.0616	0.031	0.015	0.008	0.014	0.016	0.0225	20	0
70	0.01932	0.01	0.005	0.002	0.001	0.0008	0.008	0.008	7	0

Time taken graph

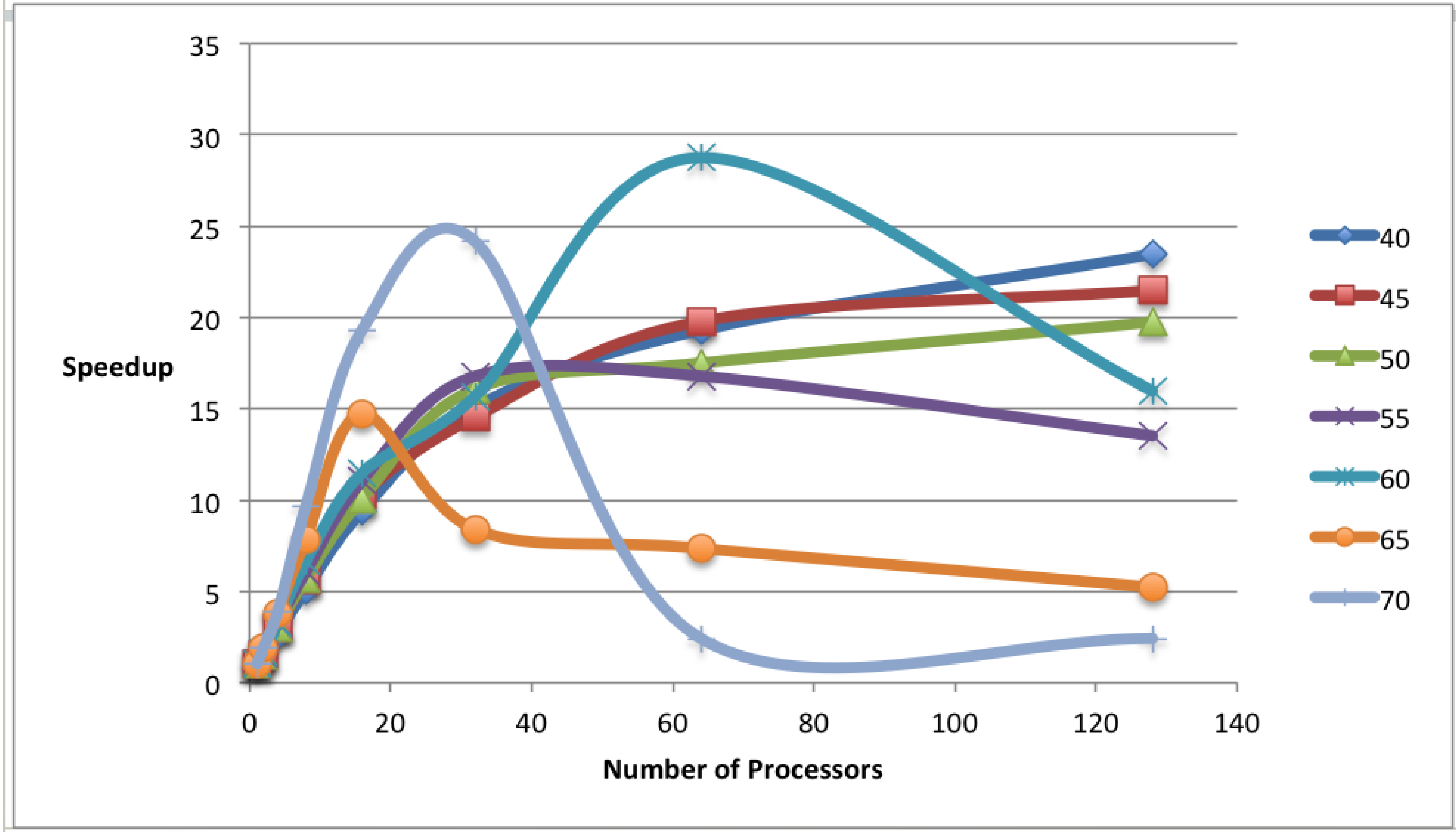


Speedup for parallel implementation

- Number of transactions =100, different number of items = 200.
- Confidence = 50

	1	2	4	8	16	32	64	128
40	1	1.324	2.655	5.072	9.416	15.094	19.29	23.447
45	1	1.472	2.979	5.654	10.245	14.546	19.787	21.472
50	1	1.479	2.982	5.678	10.081	16.084	17.499	19.734
55	1	1.557	3.244	6.069	11.061	16.783	16.783	13.519
60	1	1.691	3.254	6.634	11.5	15.68	28.752	15.972
65	1	1.907	3.79	7.833	14.687	8.392	7.343	5.222
70	1	1.932	3.864	9.66	19.32	24.15	2.415	2.415

Speed up graph



Findings from case 1

- As the support increases, the time required to solve the problem will decrease.
- As number of processors increase, the time required to solve the problem will decrease and after some processors it becomes constant.
- In case of higher support, the time taken to solve the problem might increase when the number of processors. This is assumed to be due to the large number of communications happening, when compared to the time taken to solve the problem.

CASE 2

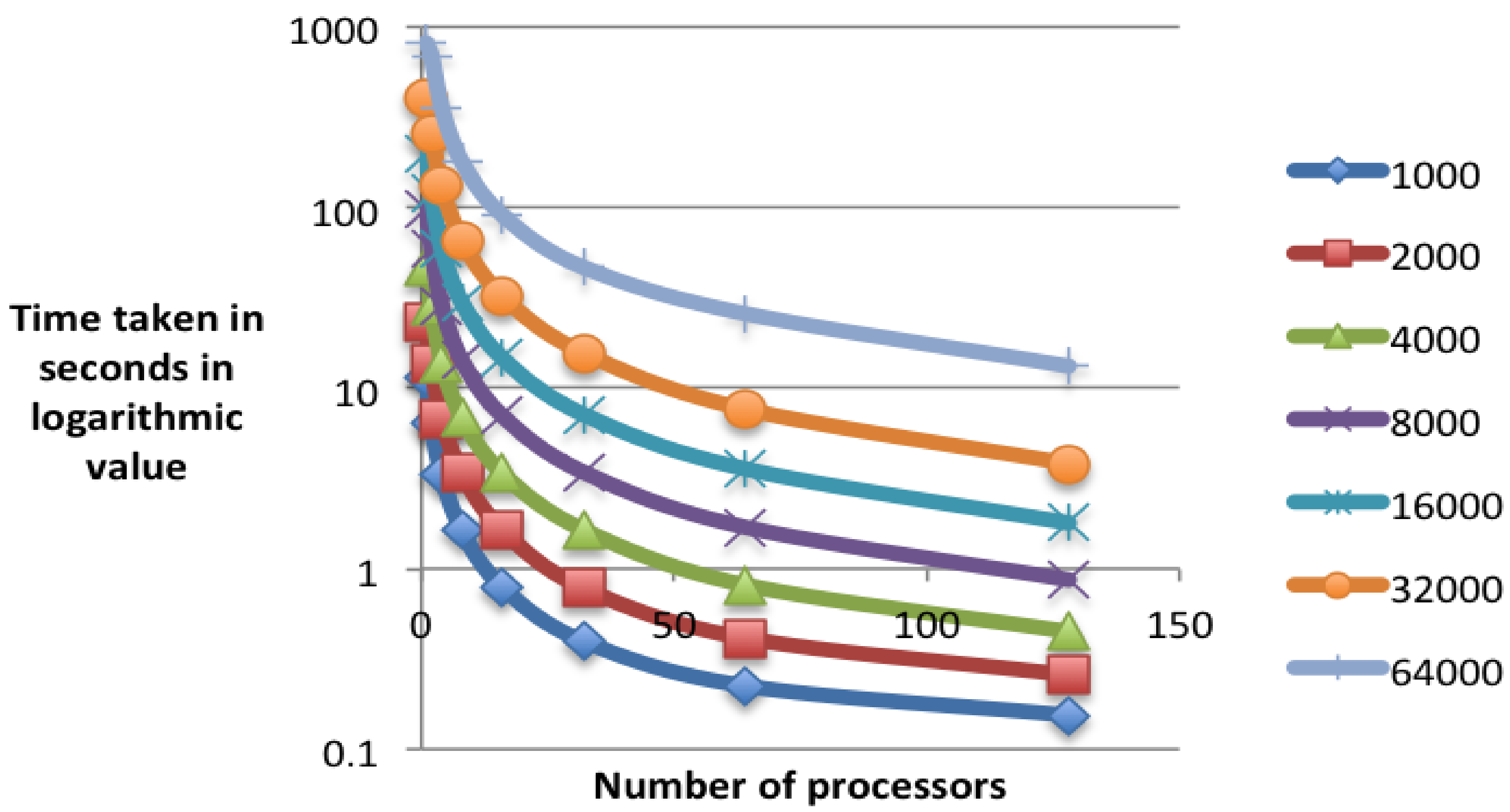
- Output for varying number of transactions
- Different transactions from 1000 to 64000 are taken.
- Support is kept at 55 and Confidence is kept at 50.

Output for varying number of transactions

- Support = 55, Confidence = 50

	1	2	4	8	16	32	64	128
1000	11.3971	6.44	3.312	1.618	0.786	0.396	0.224	0.154
2000	23.4285	13.754	6.78	3.372	1.634	0.78	0.412	0.258
4000	47.2866	28.63	13.81	6.836	3.37	1.642	0.812	0.4475
8000	98.411	59.86	28.752	14.2	7.025	3.425	1.6975	0.8675
16000	197.839	119.81	59.225	29.77	14.656	7.153	3.57	1.79
32000	402.78	254.96	132.135	66.16	32.205	15.7	7.645	3.815
64000	812.917	685.84	356.36	179.117	90.892	46.678	24.86	12.75

Time taken graph for different number of transactions

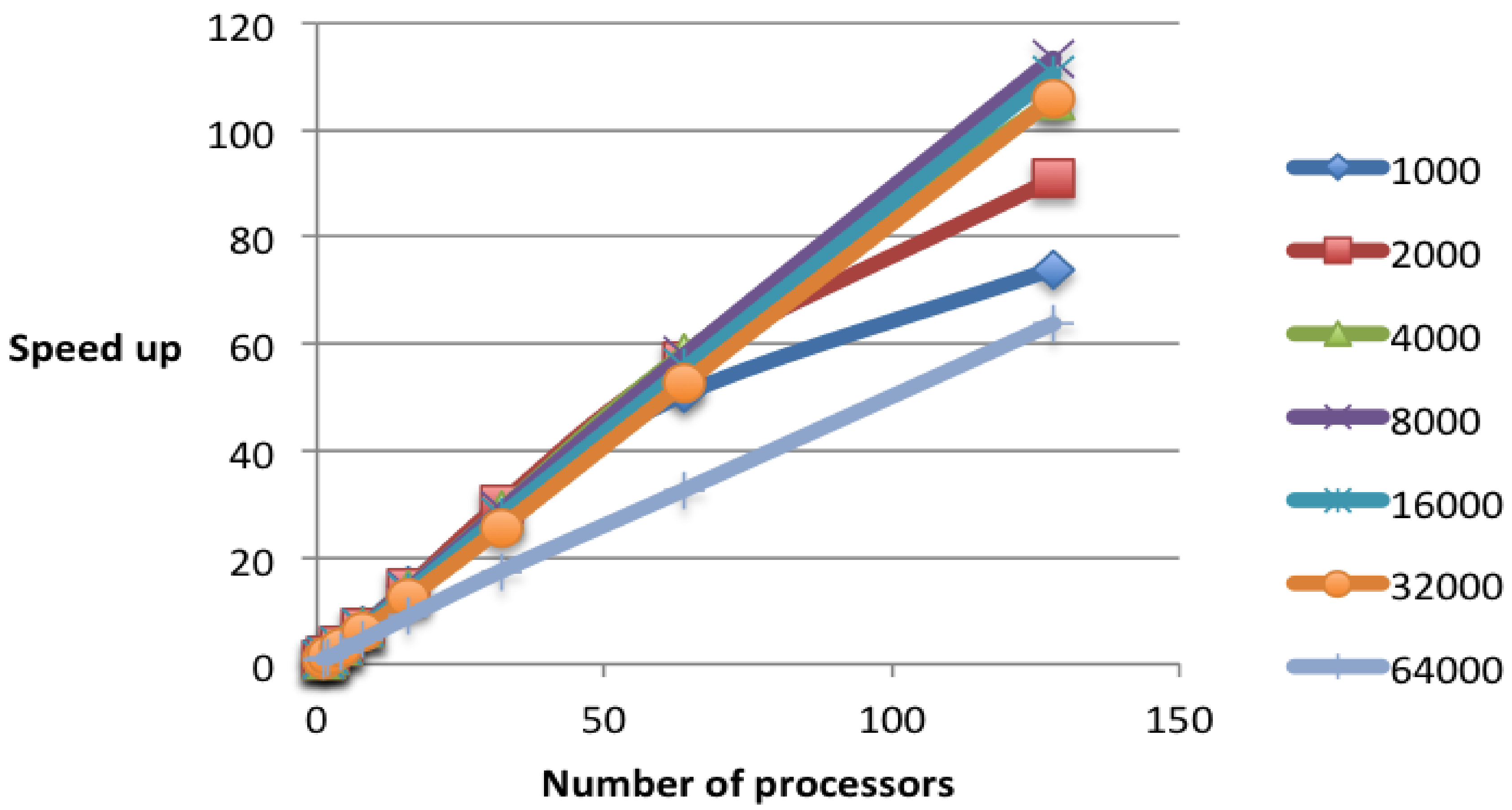


Speed up table for varying number of transactions

- Support = 55, Confidence = 50

	1	2	4	8	16	32	64	128
1000	1	1.769	3.441	7.043	14.5	28.781	50.5879	74.007
2000	1	1.703	3.455	6.947	14.338	30.036	56.865	90.808
4000	1	1.652	3.424	6.917	14.032	28.798	58.234	105.668
8000	1	1.644	3.422	6.93	14.008	28.733	57.974	113.442
16000	1	1.651	3.34	6.645	13.498	27.658	55.417	110.524
32000	1	1.579	3.048	6.087	12.506	25.524	52.685	105.877
64000	1	1.185	2.28	4.53	8.943	17.415	32.69	63.758

Speed up graph for varying number of transactions



Findings from case 2

- As the number of transactions increases, the time taken to solve the problem will also increase.
- As the number of processors increases, the time taken to solve the problem decreases and speed up will also increase.

CASE 3

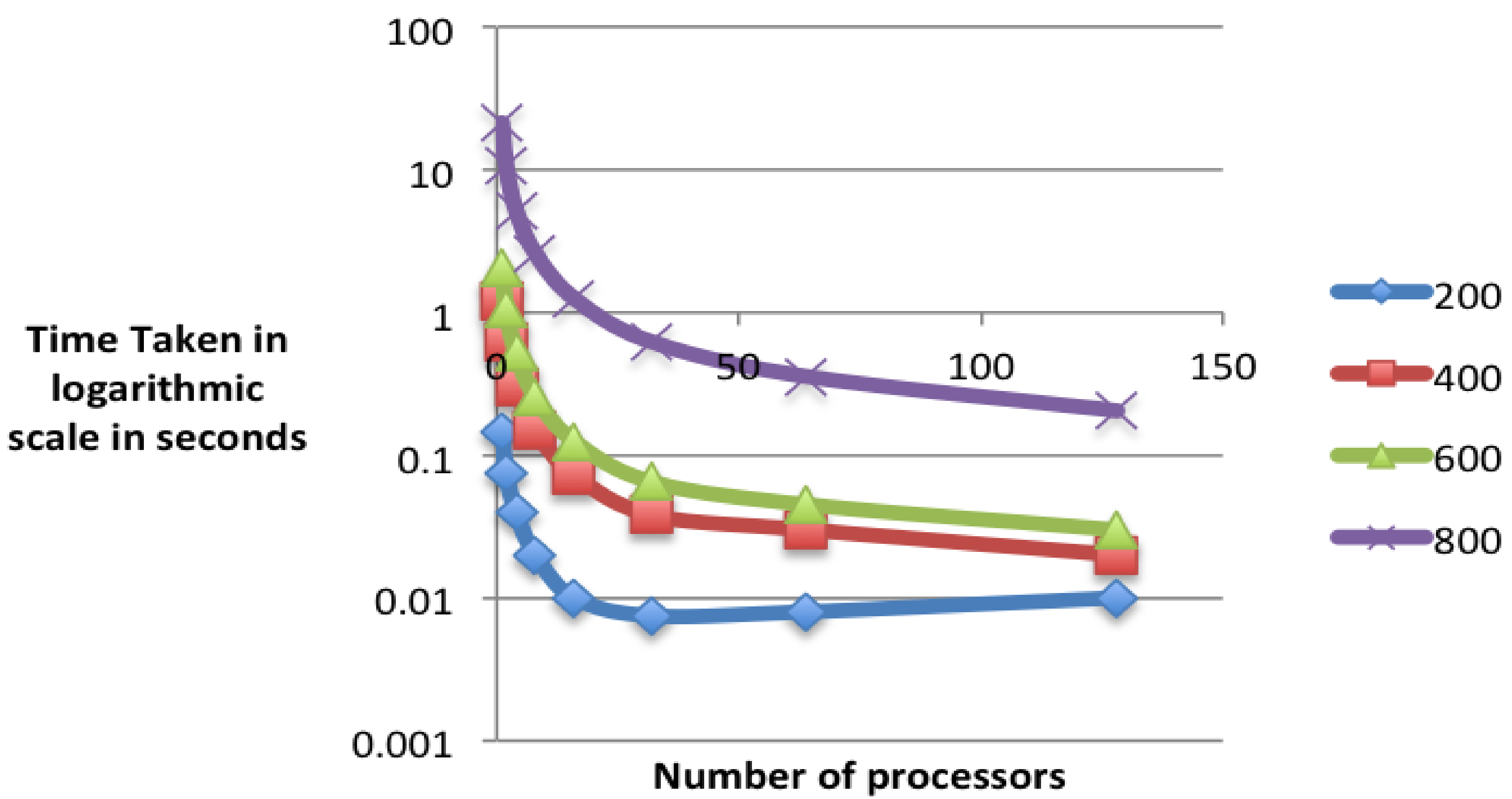
- Output for different number of item sets and with same number of transactions
- Number of transactions is constant and kept at 1000
- Support = 70 and Confidence = 50
- Item sets having values between 200 and 800 are tested.

Output for varying number of item sets

- Support = 70, Confidence = 50, Number of transactions = 1000

	1	**2**	**4**	**8**	**16**	**32**	**64**	**128**
200	0.1461	0.076	0.04	0.02	0.01	0.0075	0.008	0.01
400	1.2112	0.614	0.296	0.148	0.0729	0.038	0.03	0.02
600	2.086	1.05	0.525	0.265	0.135	0.065	0.045	0.03
800	21.2171	10.64	5.21	2.596	1.455	0.762	0.456	0.285

Time taken graph for different item sets

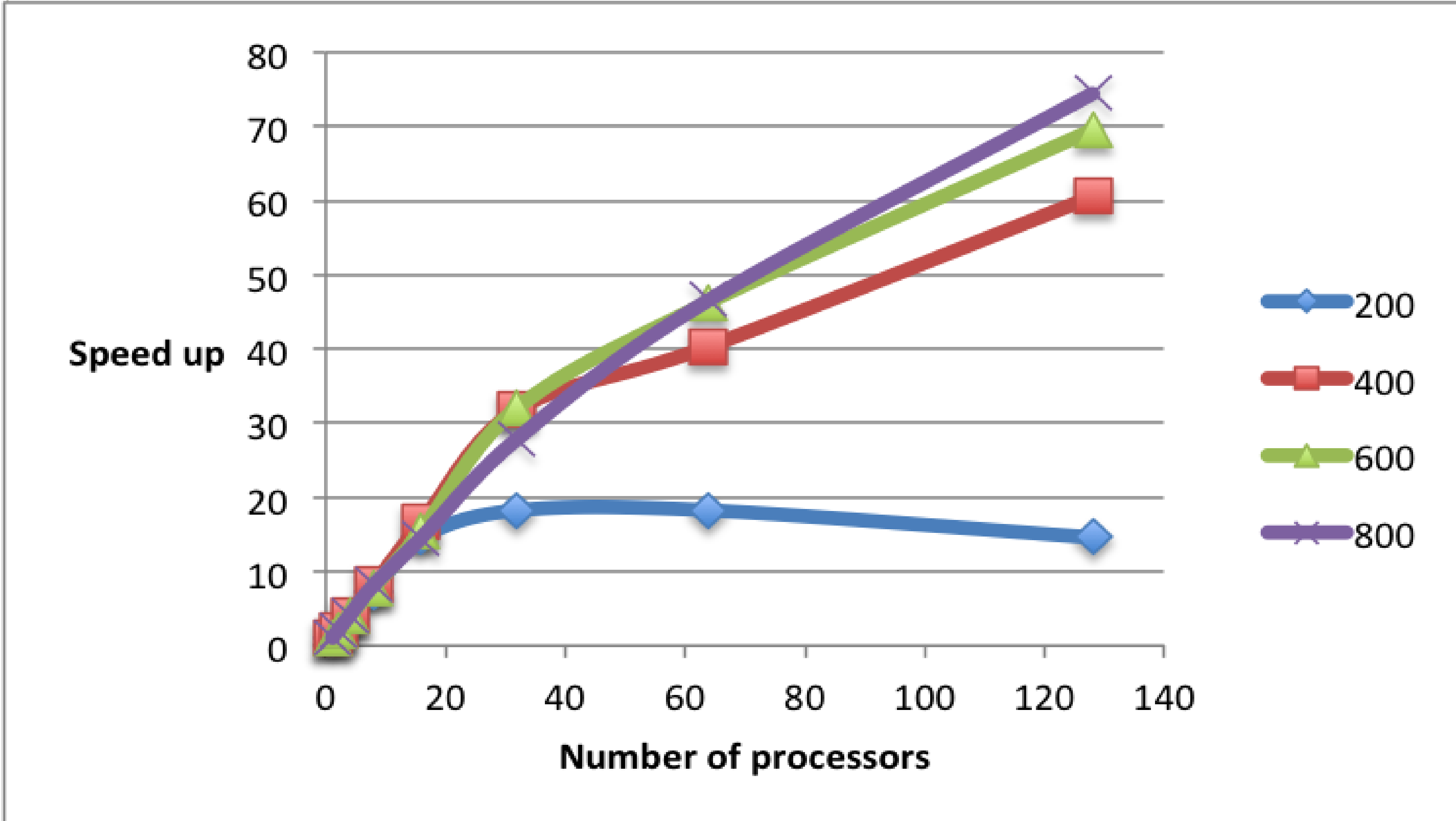


Speed up table for varying number of item sets

- Support = 70, Confidence = 50, Number of transactions = 1000

	1	2	4	8	16	32	64	128
200	1	1.921	3.65	7.3	14.6	18.25	18.25	14.6
400	1	1.972	4.091	8.182	16.589	31.868	40.366	60.55
600	1	1.986	3.973	7.87	15.45	32.09	46.35	69.55
800	1	1.994	4.072	8.174	14.58	27.91	46.64	74.44

Speed up graph for varying number of item sets



Findings from case 3

- As the number of item sets increases, the time taken to run the program will increase.
- Since high value of support is used, the time taken to run the program might increase when number of processors increases.
- This is mainly because of the large amount of communication happening in the program.

Conclusions

- Was able to identify the benefits of parallelizing.
- When number of processors was increased, corresponding reduction in time taken was clearly seen.
- The output depends on the size as well as the type of input data.

Future Work

- To implement apriori algorithm using Open MP and compare its performance with MPI implementation of the same.

References

1. http://rakesh.agrawal-family.com/papers/tkde96passoc_rj.pdf
2. http://www.cse.buffalo.edu/faculty/azhang/cse601/


Q&A


Thanks!