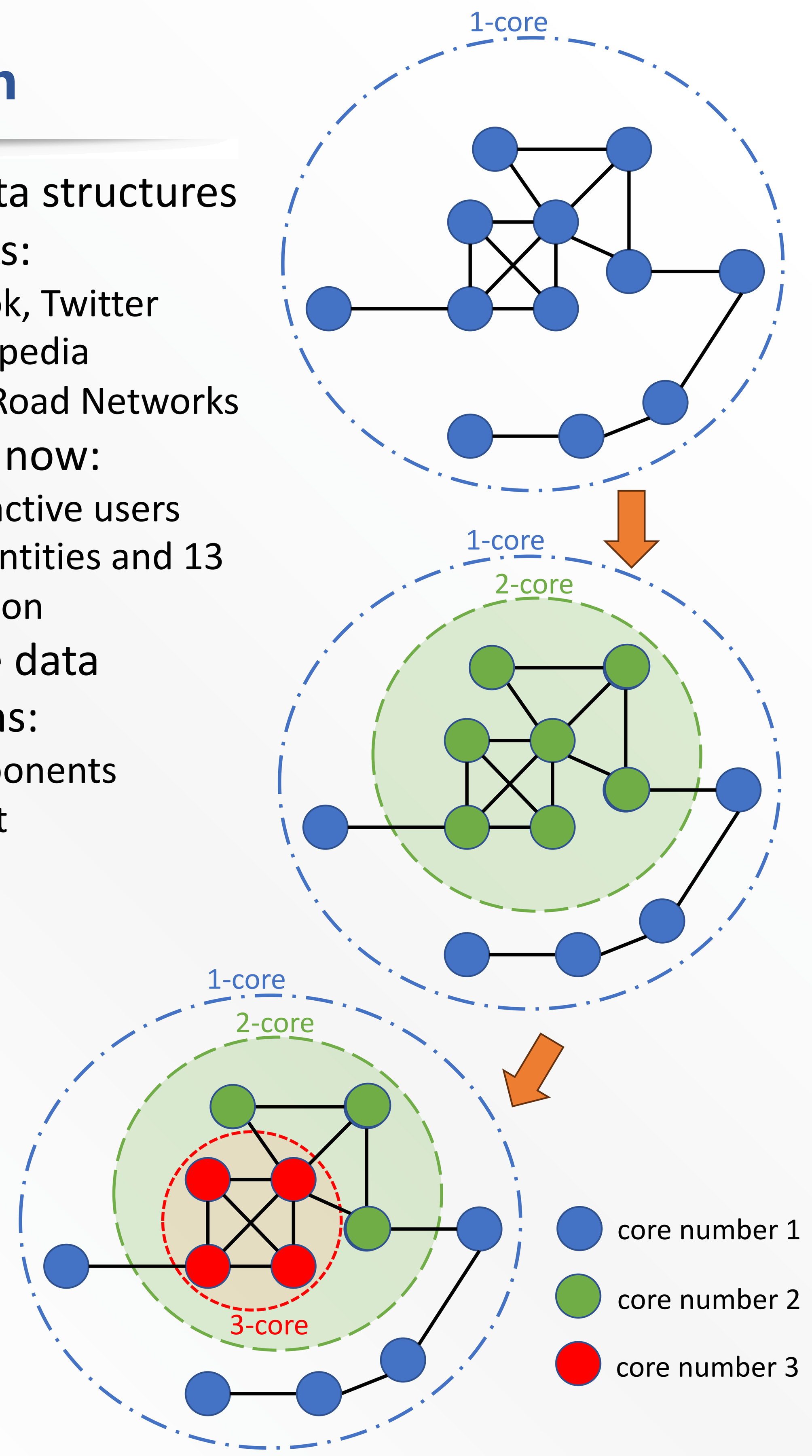
Parallel Order-Based Core Maintenance in Dynamic Graphs

Bin Guo (guob15@mcmaster.ca)• Emil Sekerinski
Department of Computing and Software, McMaster University

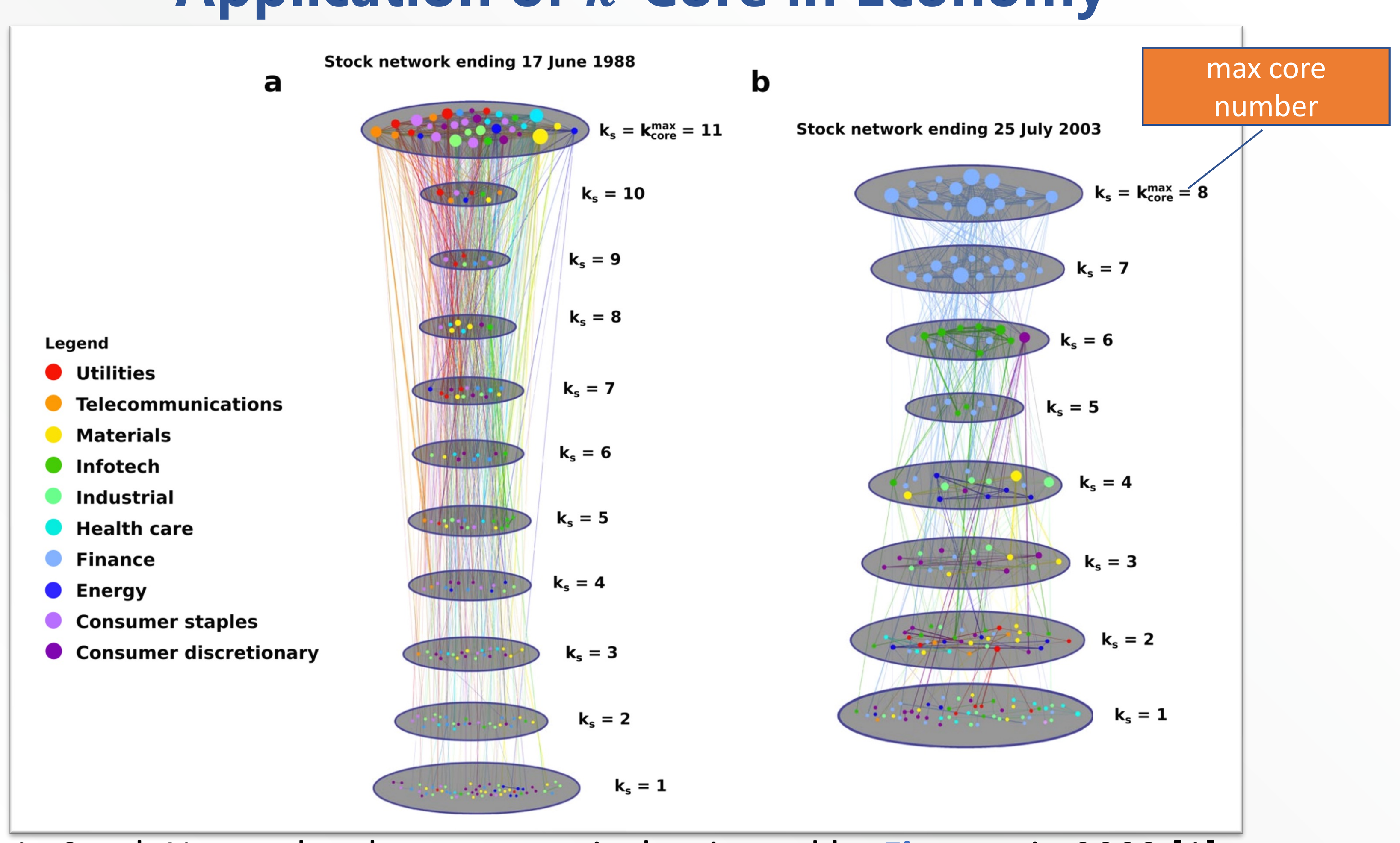
Motivation

- Graphs are important data structures used in many applications:
  - Social Networks: Facebook, Twitter
  - Knowledge Networks: Dbpedia
  - Biological Networks and Road Networks
- Data graphs can be large now:
  - Facebook has 2.9 billion active users
  - DBpedia has 6.6 million entities and 13 billion pieces of information
- Large data graphs require data analytics Graph algorithms:
  - Strongly Connected Components
  - Minimum Spanning Forest
  - Shortest Path Distance
  - k-Core



- ***k*-Core Decomposition** is to Find the largest subgraph, in which each node has at least k neighbours
- The core number is the largest value of k
- It is to find the dense part in a graph

Application of k-Core in Economy



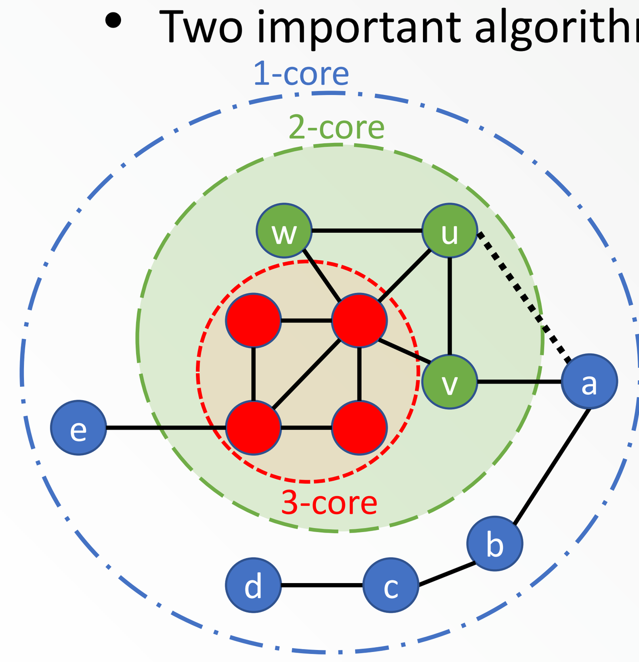
- In Stock Networks, the max core is dominated by Finance in 2003 [1]
- Finance has huge effects to economy

Sequential Order-based Core Maintenance

- Dynamic graphs change with new edges inserted or old edge removed, e.g. temporal graphs
- Recalculate the core numbers is expensive
- Instead, we maintain the core numbers in dynamic graphs

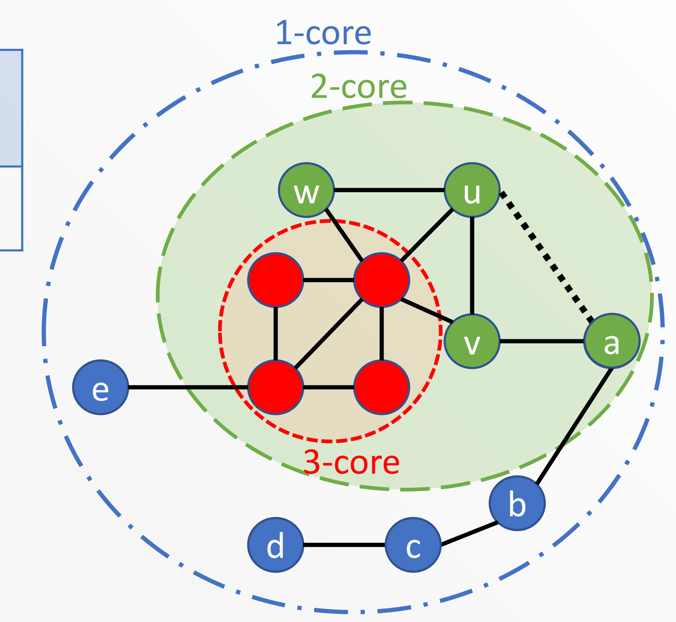
Edge Insertion:

- Maintain the core numbers when inserting one edge (u, a)
- The key step is to identify two set: V^* and V^+
- Two important algorithms: **Traversal** [2] and **Order** [3]



V^*	All vertices with core number changed
V^+	All searched vertices

By inserting an edge (**u**, **a**), the core number of **a** increased from 1 to2



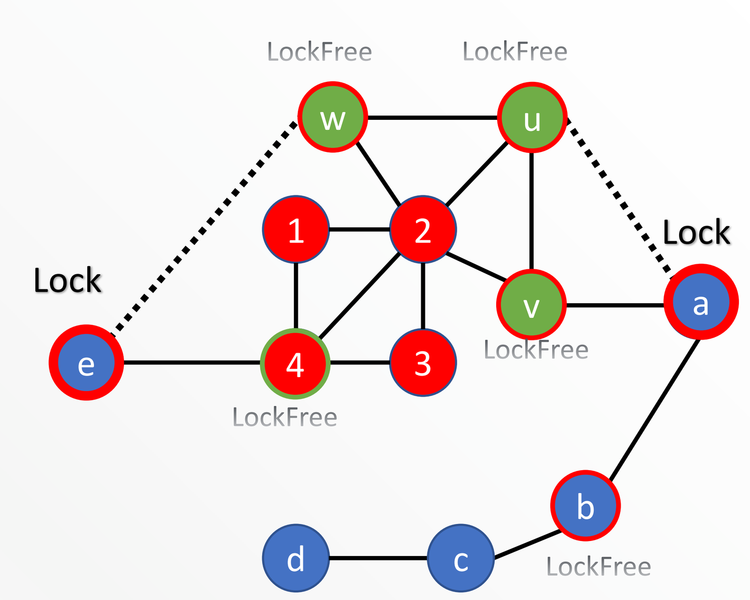
Traversal	Order
$V^* = \{a\}$ $V^+ = \{a, b, c, d\}$	$V^* = \{a\}$ $V^+ = \{a\}$
By traversing the vertices in DFS	By traversing the vertices in order of {d, c, b, a, e}, so that b, c, d can be omitted

Our Parallel Order-Based Core Maintenance

- Existing parallel methods are based on the **Traversal** algorithms
- We are the first to **parallelize** the **Order** algorithm

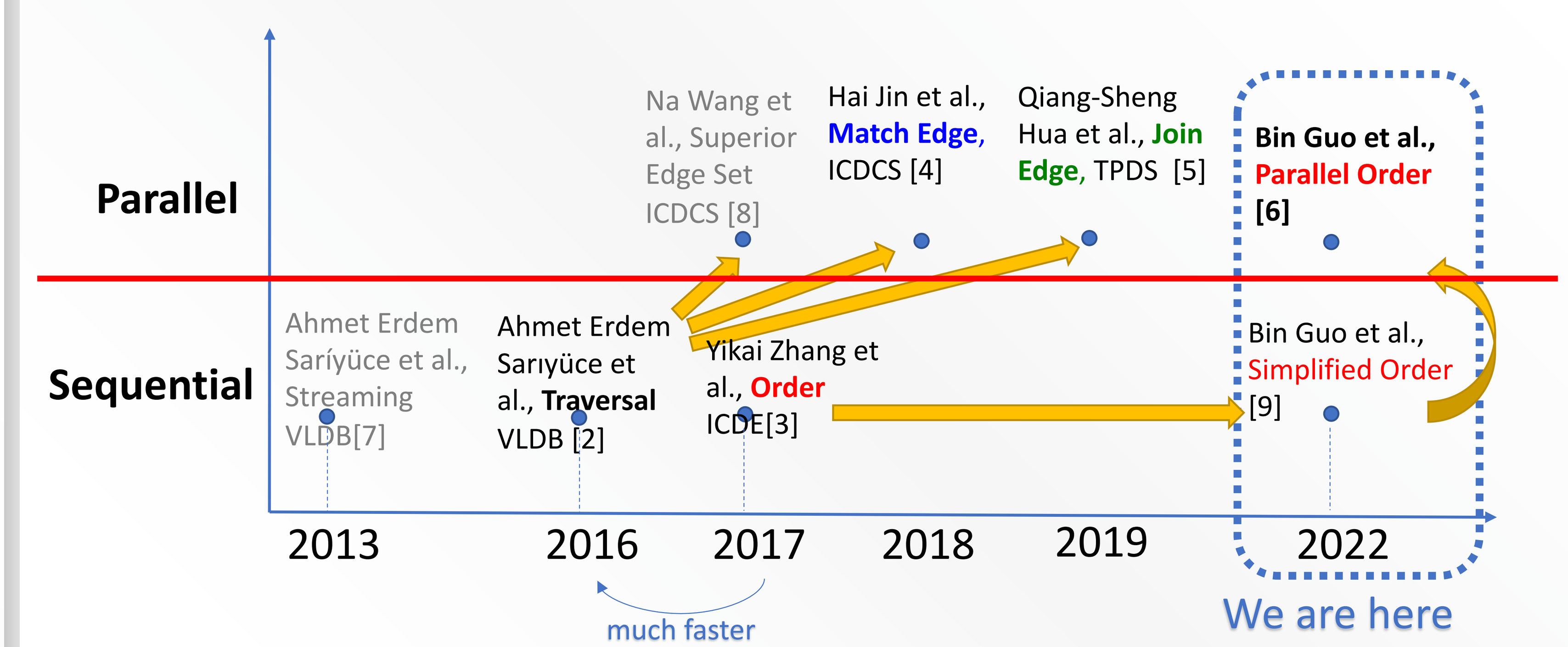
Parallel Edge Insertion:

- Maintain the core numbers when inserting two edge (u, a) and (w, e) in parallel
- For synchronization, the vertices in V^+ are locked, all associated edges are lock free.
- Since vertices are much less than edges in graphs, the synchronization overhead is significantly reduced

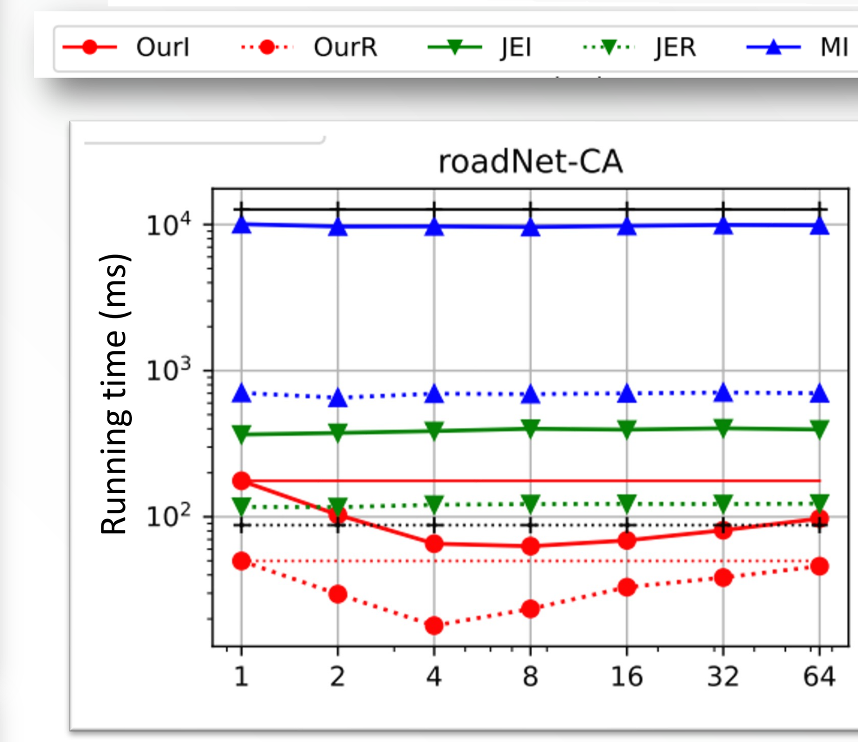


$$V^* = \{a, e\}$$
$$V^+ = \{a, e\}$$

Studies of Core Maintenance



Experiment Evaluation



OurI	Our Insert [6]
OurR	Our Remove [6]
JEI	Join Edge Insert [5]
JER	Join Edge Remove [5]
MI	Match Edge Insert [4]
MR	Match Edge Remove [4]
OI	Sequential Order Insert [3]
OR	Sequential Order Remove [3]
TI	Sequential Traversal Insert [2]
TR	Sequential Traversal Remove [2]

References

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