Distributed Computing with MPI

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Outline

- Introduction
    - Motivation
    - MPI-1 and MPI-2 statuses
- Machine Learning with MPI
- Deadlock and Knot detection/removal
- Determining Computation End
- Conclusion

Motivation

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Cluster Computing

Figure: Example of computer cluster [Source: Boise State CS Dept, Beowulf Cluster Lab (http://cs.boisestate.edu/∼amit/research/beowulf/)]

MPI-1

- MPI is a message passing interface library standard
  - Is a specification, not an implementation
  - Library, not a language
  - Based on the classical message passing programming model
  - Barriers
  - Multi-Party messages
    - 1:n $\rightarrow$ *broadcast*
    - n:1 $\rightarrow$ *reduce* (Hadoop)
    - n:n $\rightarrow$ *all-to-all* (1-step consensus)

MPI-1

- MPI was defined in 1994 [1] by a broadly-based group of parallel computer vendors, computer scientists, and application developers.
- Implementations and support grew quickly
- Basis for cluster environments with free and open implementations (OpenMPI, MPICH2, ...)

[1] I. Foster, *Designing and Building Parallel Programs*. Addison-Wesley, 1994, online Ch. 8 - Message Passing Interface

MPI-2

- Same as MPI-1 with extended functionality
- Extends message passing model
  - Parallel I/O
  - Remote memory operations (not covered here)
  - Dynamic process management
- Adds bindings to include C++ and Fortran-90
- Interaction with Threads

MPI-2 Status

- Most parallel systems implement some implementation of MPI-2
- Cluster MPIs, such as MPICH2 and LAM, support most of MPI-2 including dynamic process management
- We'll refer mostly to the OpenMPI implementation

Problem Definition

- Problem Types solved by MPI
  - Large Dataset Processing
  - Decreased Computation Time (if possible)
  - Redundancy for Distributed Systems
- Example System Definition
  - Deepthought: (Beowulf Cluster)
  - 15 Nodes
  - Each node has a dual-core Pentium IV processor
  - 1 GB of RAM
  - 1 (non-included node) as coordinator

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MPI Uses for machine learning applications

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Logistic Regression Plot

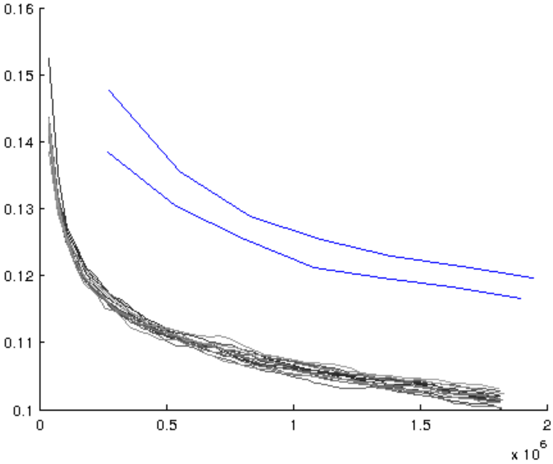

Figure: Results of parallel Logistic Regression(x-axis denotes time and y-axis is error on test set)

Deadlock Detection

- Many works into this (Example[2])
- Determine if directed cyclic graph exists in network

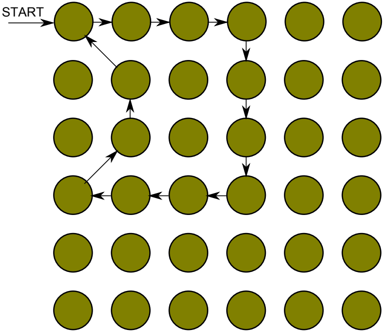

Figure: Example of cyclic graph in network

[2] K. M. Chandy, J. Misra, and L. M. Haas, "Distributed deadlock detection," *ACM Trans. Comput. Syst.*, vol. 1, no. 2, pp. 144–156, May 1983

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Knot Detection

Knots are a special case of deadlocks[3]

- Cause larger problems
- Killing any single cycle may not kill all cycles
- What should we do here?

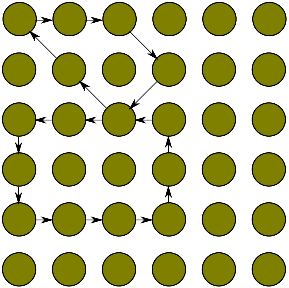

Figure: Example of network graph with knot

[3] J. Misra and K. M. Chandy, "A distributed graph algorithm: Knot detection," *ACM Trans. Program. Lang. Syst.*, vol. 4, no. 4, pp. 678–686, Oct. 1982

Multiple Knots

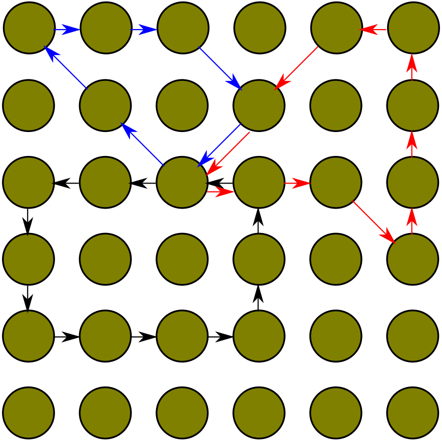

Figure: Graph with multiple (>2) distinct cycles, forming multiple knots

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Naive Computation End Algorithm

Setup:

- Ring network
- Single marker used at a time[4]
- White determines node is idle
- Black means node is currently responding to a message (i.e. computing)
- Marker colors node white when it leaves that node if idle
- If marker sees a white node, assumed white since last iteration

[4] J. Misra, "Detecting termination of distributed computations using markers," in *Proceedings of the second annual ACM symposium on Principles of distributed computing*, ser. PODC '83. New York, NY, USA: ACM, 1983, pp. 290–294

Example Network Graph

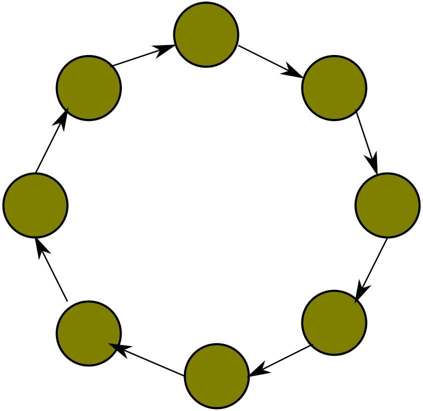


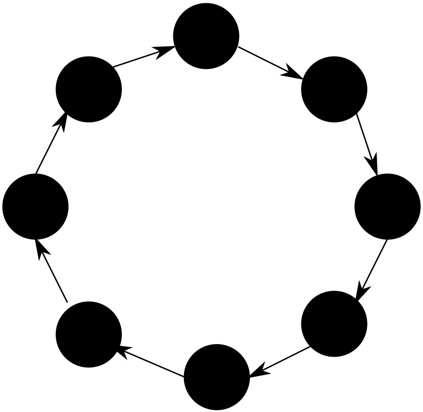
Figure: Example ring network graph

Naive Computation End Algorithm

Algorithm:

- INIT: $\forall$nodes $(n) \in N$: color black
- n_i sends initial marker m along outgoing edge
- Node n_j, where n_j is the child of n_i forwards message with following properties:
  - 0, if n_j is black
  - $m+1$, if n_j is white
  - Marker paints node white
  - If node receives message, paints itself black
- Termination is achieved when $m = N$
- Collect data at gate, and return

Algorithm by example



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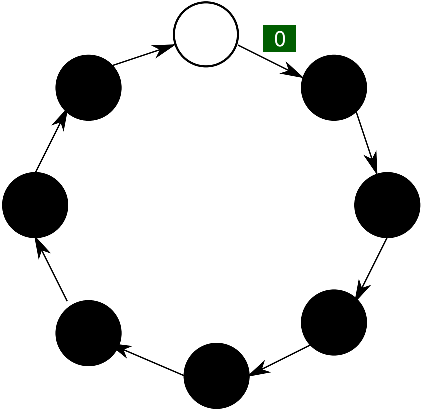

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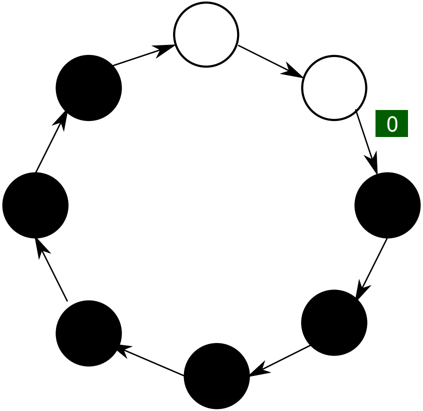

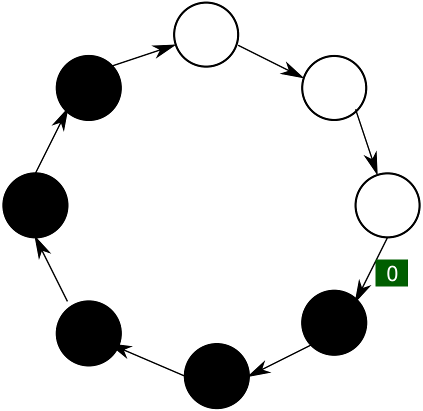
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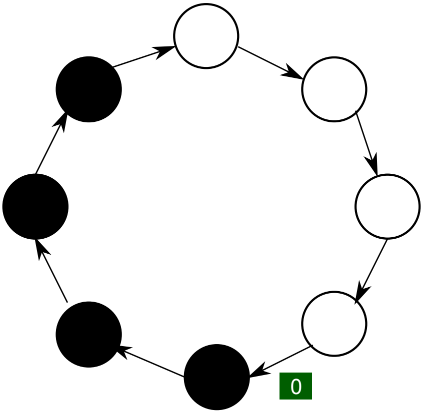

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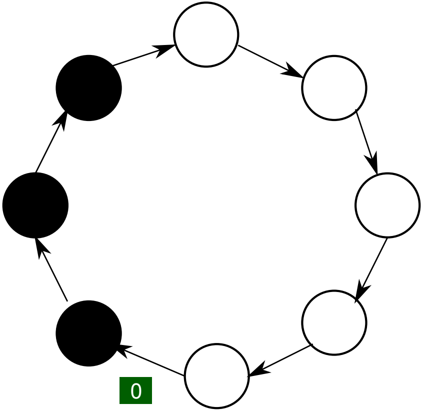

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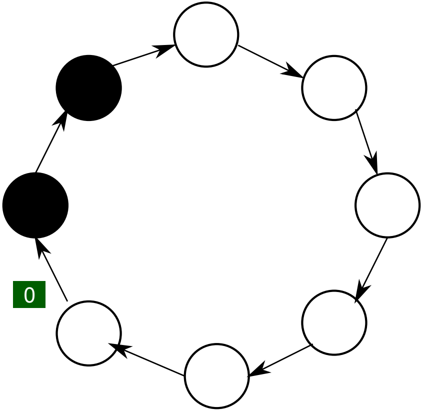

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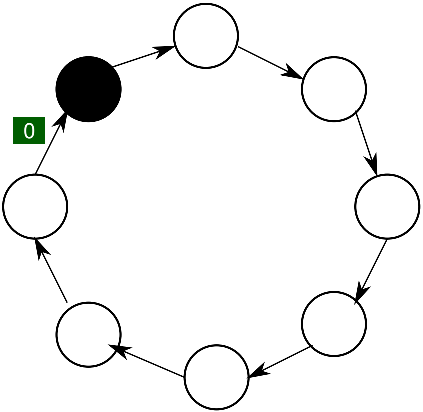

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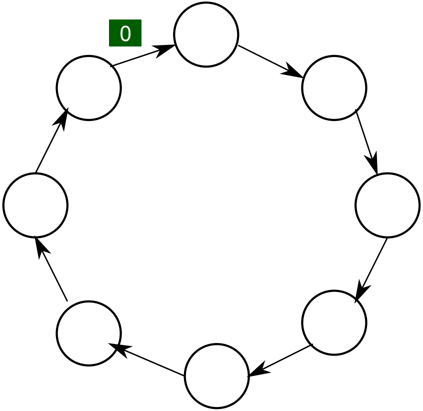

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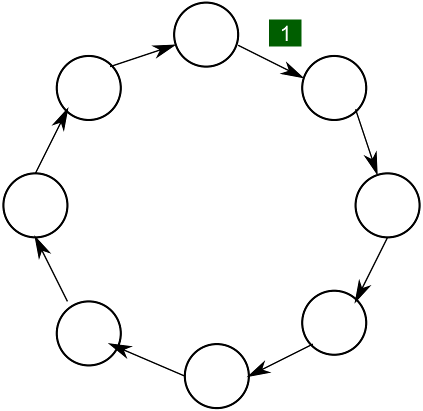

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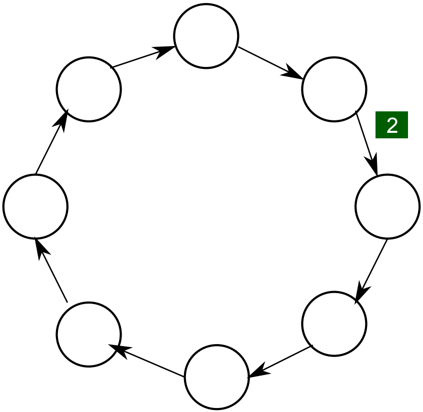

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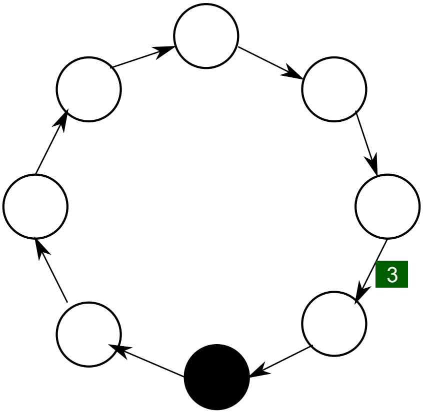

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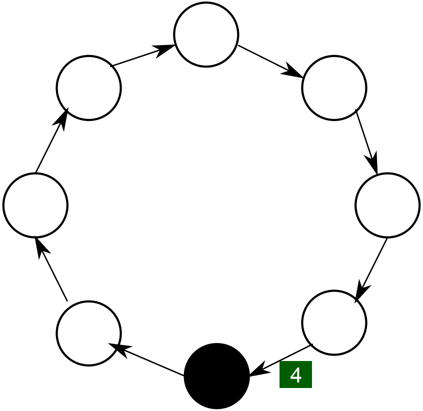

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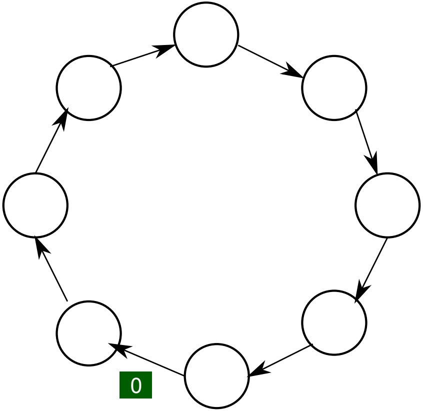

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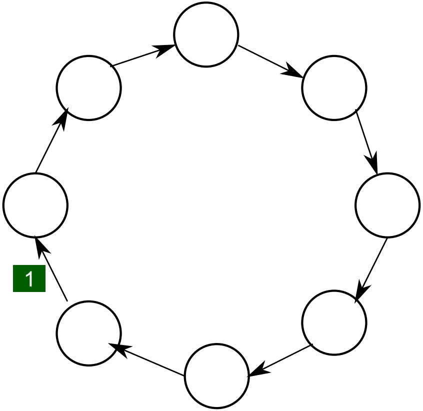

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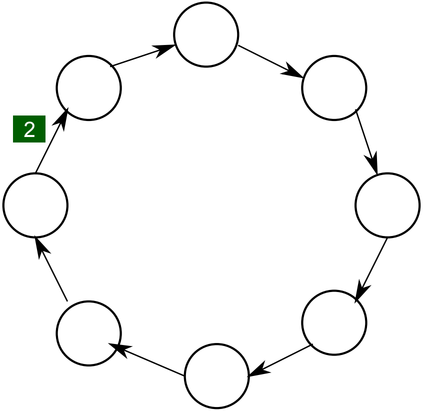

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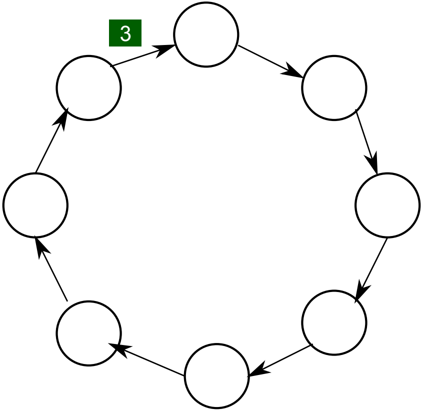

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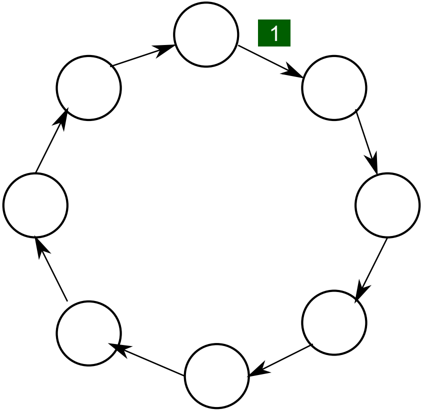

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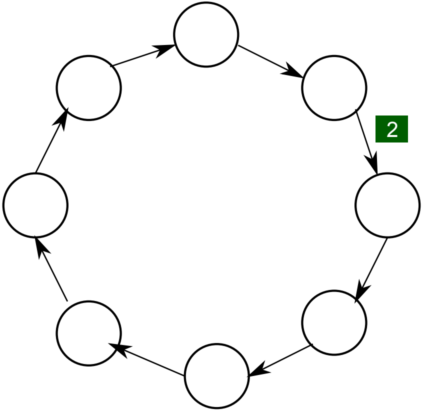

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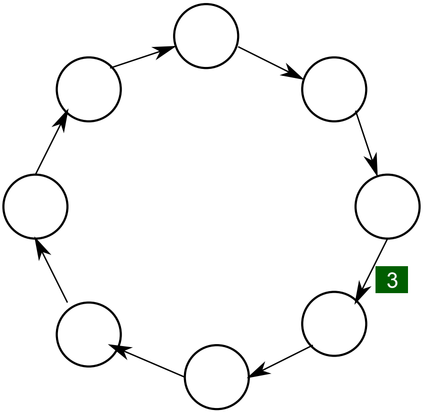

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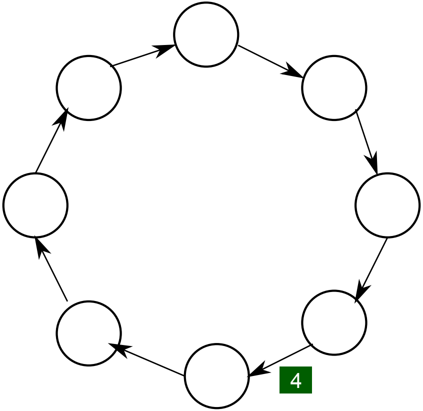

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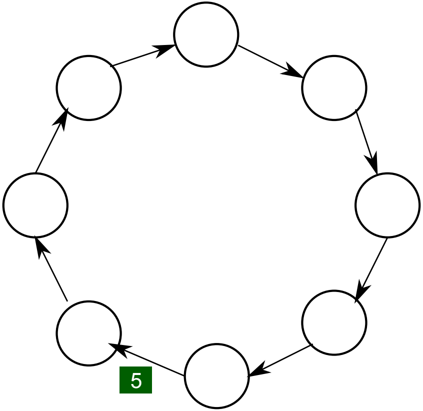

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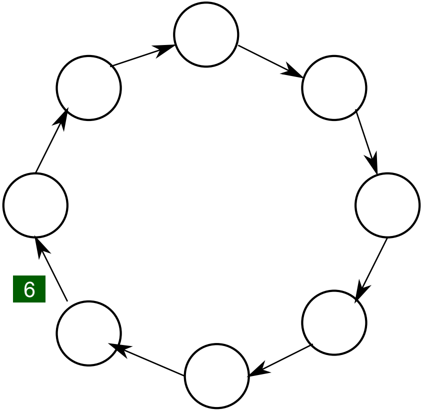

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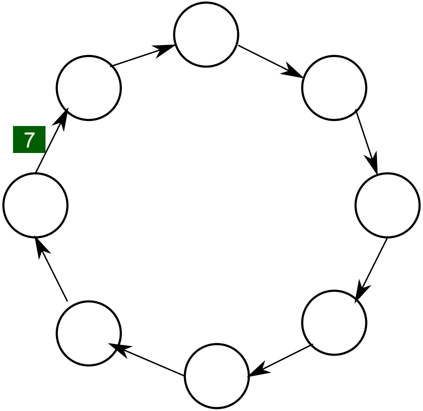

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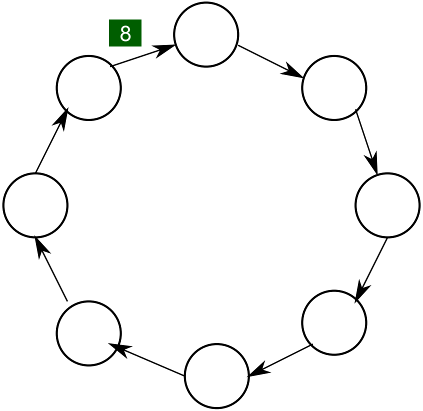

Conclusion

- Definition of MPI 1 and 2
- How MPI can be leveraged for distributed computation
- Determining cyclic graphs and avoiding them
- Determining computation end on the fly

Thank you

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Questions?