A P2P Architecture for a Large-Scale Dynamic Grid?

Márk Jelasity

University of Bologna
Italy

Project funded by the Future and Emerging Technologies arm of the IST Programme

P2P and Grid

- P2P
  - ad hoc group
    - independent
    - uncontrolled
  - fixed purpose
  - very large-scale
  - dynamic
  - unreliable
- Grid
  - more control over resources
  - general purpose (middleware)
  - not as large-scale
  - not as dynamic
  - not as unreliable

Crossover

- P2P
  - ad hoc group
    - independent
    - uncontrolled
  - fixed purpose
  - very large-scale
  - dynamic
  - unreliable
- Grid
  - more control over resources
  - general purpose (middleware)
  - not as large-scale
  - not as dynamic
  - not as unreliable

Scenario from a user's point of view

- User prepares application against an API
  - API contains calls to services such as search, multicast, aggregation, monitoring, etc
- User is assigned a P2P network which supports the services needed by the application
  - assigned network is a real P2P network: dynamic, unreliable, maybe very large-scale, etc
  - but with the required services and contracts
- User executes the application
- The P2P network that was assigned is recycled

How to support this?

- A global pool needs to be maintained
- Partitions of this pool need to be separated and assigned
- The infrastructure that implements the services over the given partition needs to be built
- The application of the user needs to be executed
- Cleanup needs to be performed

For completeness...

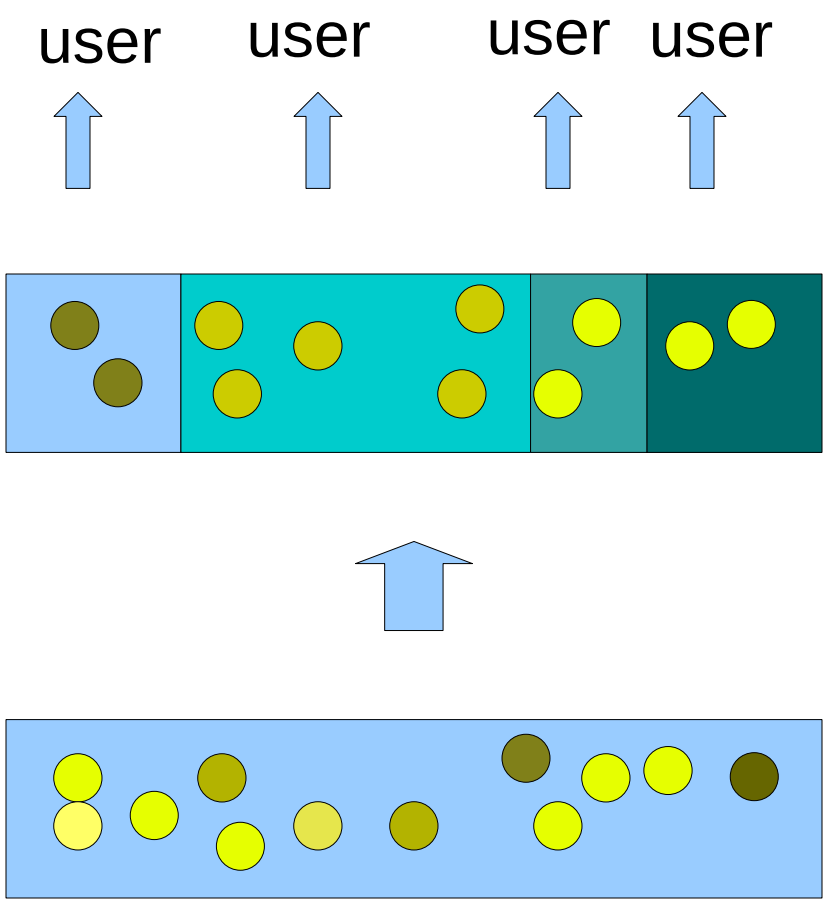
- The protocols that implement these functions need to be
  - lightweight
    - simple
    - efficient
  - effective
  - reliable
  - self-managing (only high level human involvement)

The global pool

- requirements
  - provide a group abstraction
  - minimal functionality but
  - extremely reliable and robust
- solution
  - peer sampling service abstraction
    - getRandomPeer()
  - implementation
    - unstructured overlay network maintained by gossip
    - newscast, lpbcast, cyclon, etc

The creation of partitions

- work in progress...
- partitions also implement peer sampling service
  - recursive structure
- partitions are abstact and maintained (filled in) dynamically by actual set of nodes

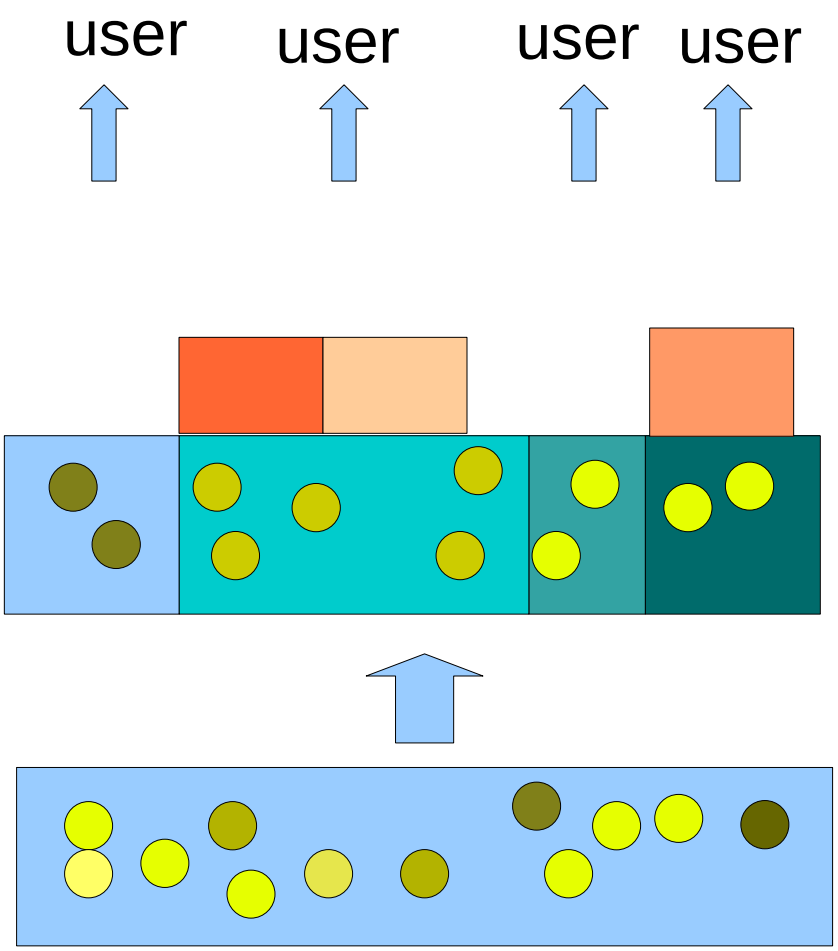


The creation of partitions

- Partitions are dynamic
  - they are constantly created and dissolved on demand
  - even when the set of partitions is constant, they change due to
    - churn
    - changing properties of nodes
  - The main challenge is this dynamism

Building the architecture

- the applications will need services, such as a DHT or proximity overlay
- we need to build those on top of the respective partitions (ie, the peer sampling service)



Building the architecture

- achieved through the bootstraping service
  - P2P services are based on overlay networks
  - the bootstrapping service must build arbitrary overlay networks (semantic, proximity, several DHT-s, etc) quickly, reliably and cheaply
  - should rely only on the peer sampling service
- we implement it based on a gossiping scheme as well, very similarly to the peer sampling service (T-Man)

Executing the application

- just vague ideas
  - content distribution to spread the clients
  - start them all in a reasonable interval
  - monitoring, administration, etc...

Cleaning up

- The easiest: do nothing
  - all constructs are disposable, the nodes involved in the partition will automatically join other partitions when their partition is removed

Some thoughts

- the components are useful outside of this vision too
  - maintaining a specified partitioning
  - bootstrapping different overlay networks (P2P services) on demand

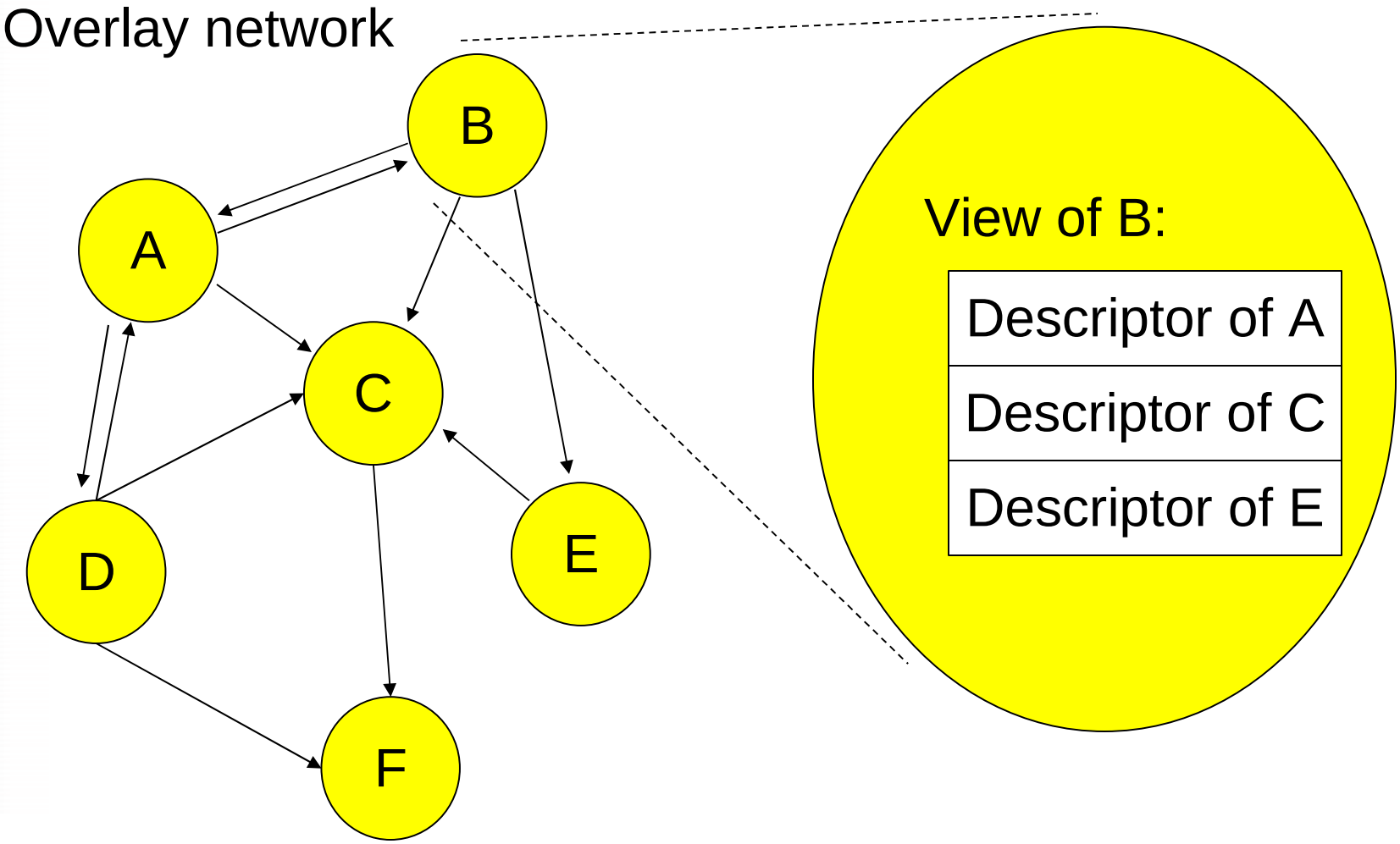
Summary

- A global pool needs to be maintained
  - peer sampling service: gossip-based implementation
- Partitions of this pool need to be separated and assigned
  - creating the partitions is work in progress
  - separate peer sampling service for partitions (similar gossip-based implementation)
- The infrastructure that implements the services over the given partition needs to be built
  - bootstrapping service: T-Man: gossip-based protocol too

Overlay networks

- Most problems boil down to building and maintaining overlay networks: the protocols then are simple
  - peer sampling: random overlay
  - bootstrapping: arbitrary overlay
- overlay networks
  - Nodes are computing devices connected to a computer network
  - Neighbours are defined by the “knows-about” relation (NOT physical neighbors in the network).
    - Can be easily adapted (unlike physical networks) by simply exchanging information

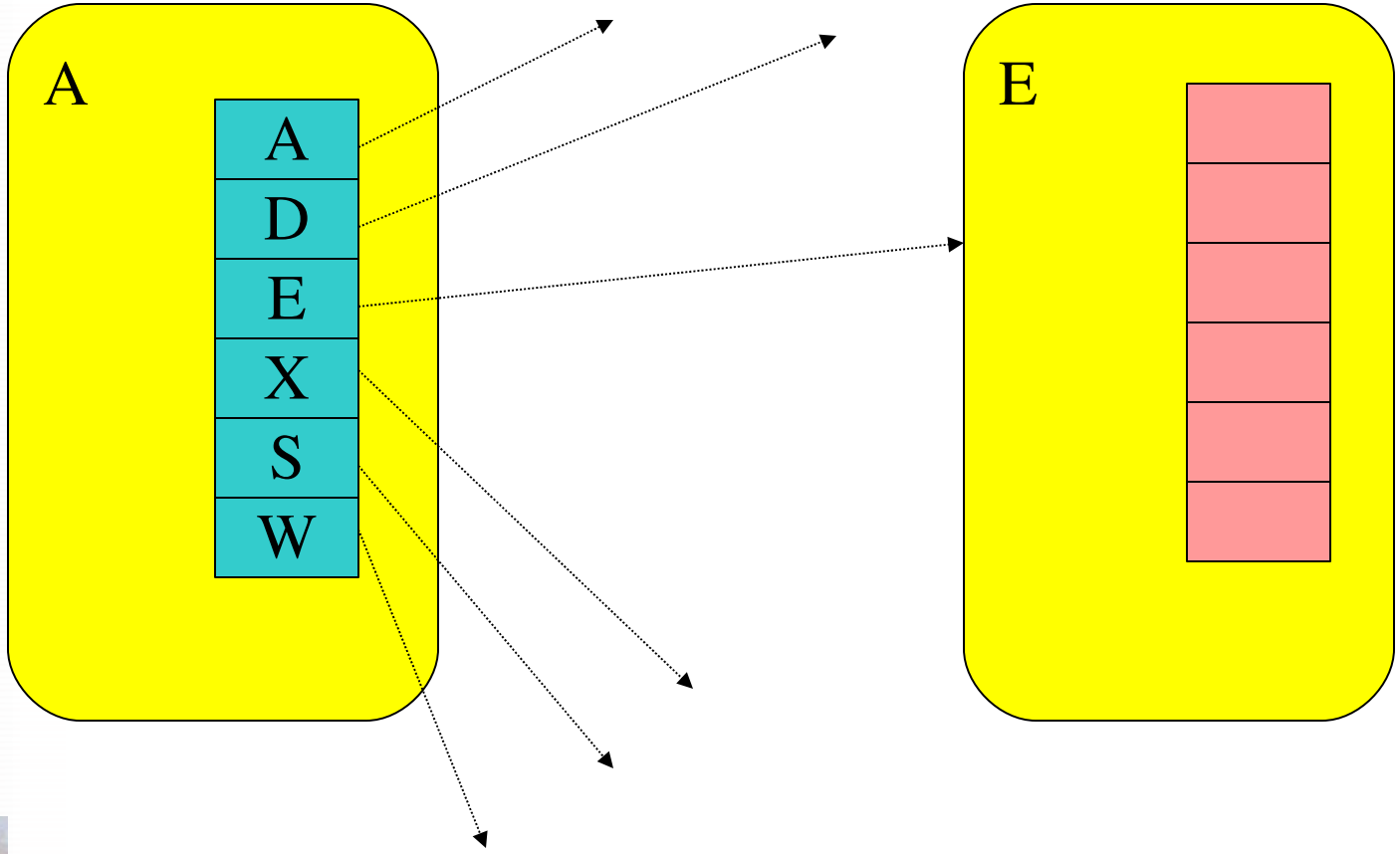
System Abstraction: basic concepts



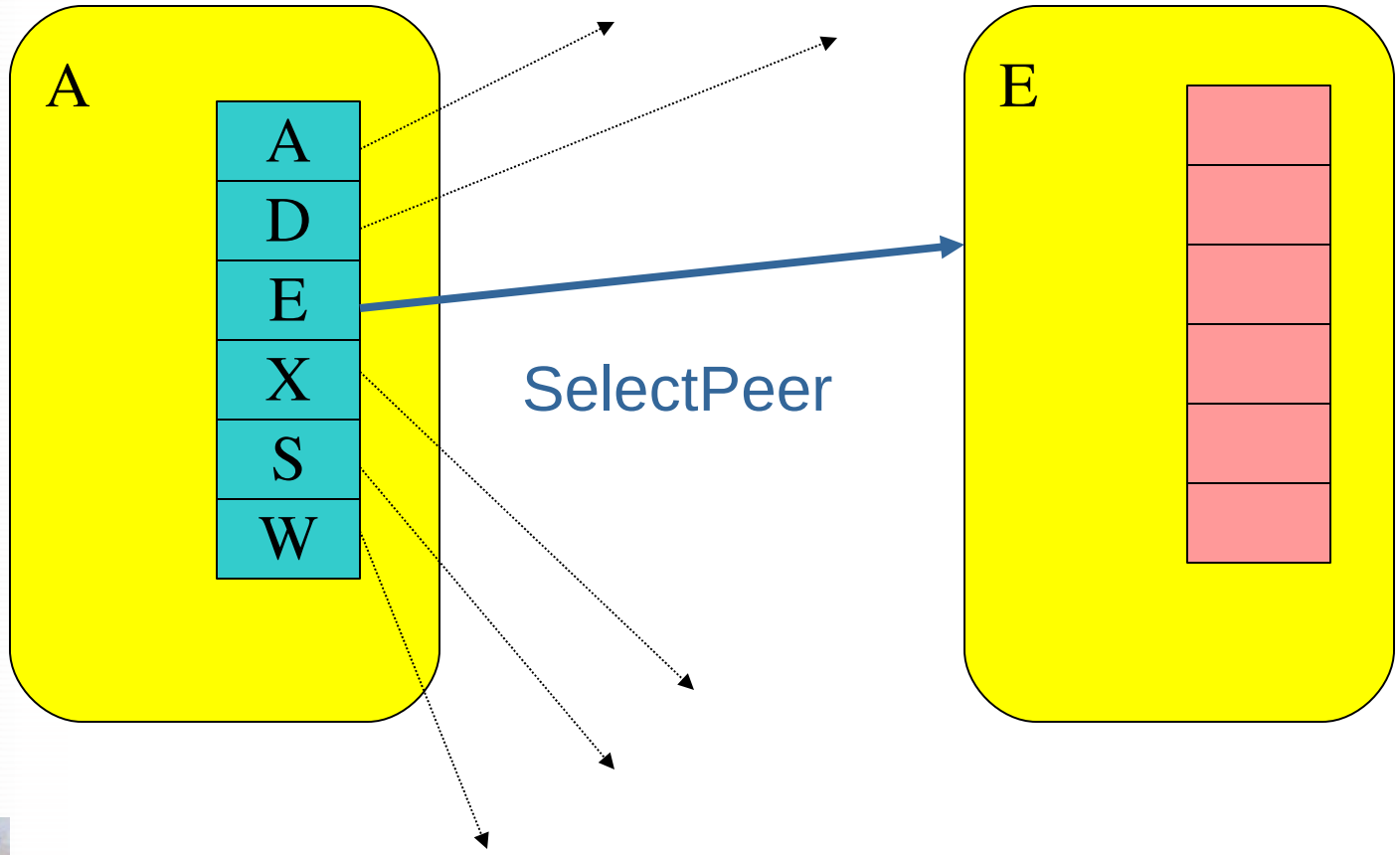
Solution: Self-organization through gossip

- The solution needs to be robust, scalable, efficient and cheap: needs to be fully distributed
  - No single point of failure, no bottlenecks, no critical components, negligable maintenance cost
- Fully distributed: need to involve self-organization
  - Gossip paradigm: a generalization of cellular automata
    - Arbitrary interconnection of nodes (cells)
    - Assynchronous
    - Nodes have arbitrary computing capabilities and send arbitrary messages

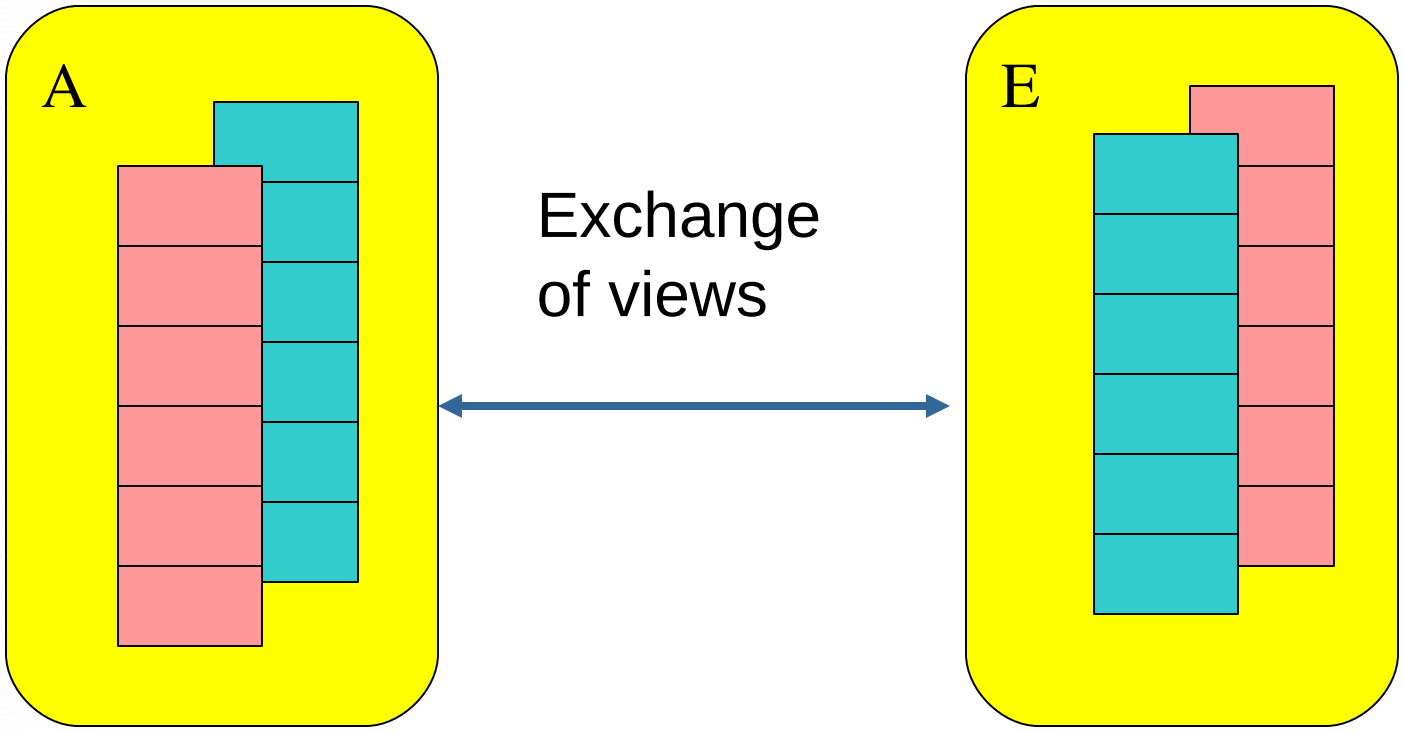
Gossip protocols for topology management



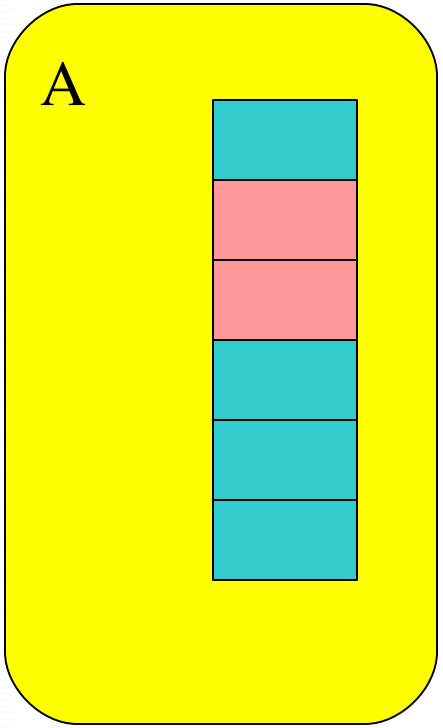
Gossip protocols for topology management



Gossip protocols for topology management

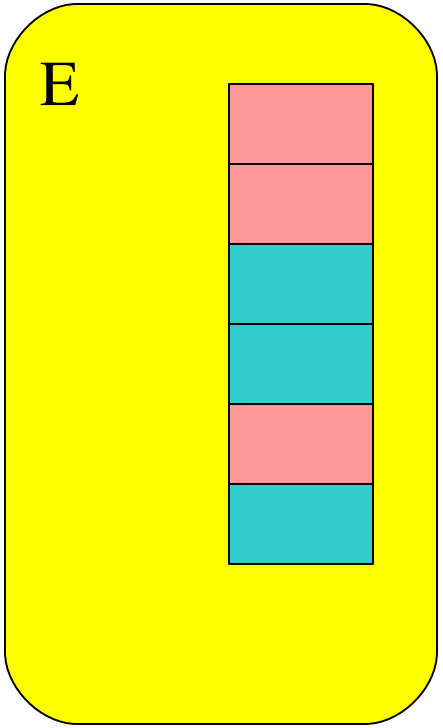


Gossip protocols for topology management



Both sides apply update

thereby redefining topology



Gossip protocols for topology management

- Fully symmetric and decentralized model
- Components of the framework
  - node descriptors: in the view we store not only the address but additional information as well about the nodes
  - selectPeer: uses the actual view to select a peer to contact
  - update($view_1$, $view_2$): based on information available on the peer nodes in the views (node descriptors) constructs the next view

peer sampling: a gossip protocol for unstructured topologies

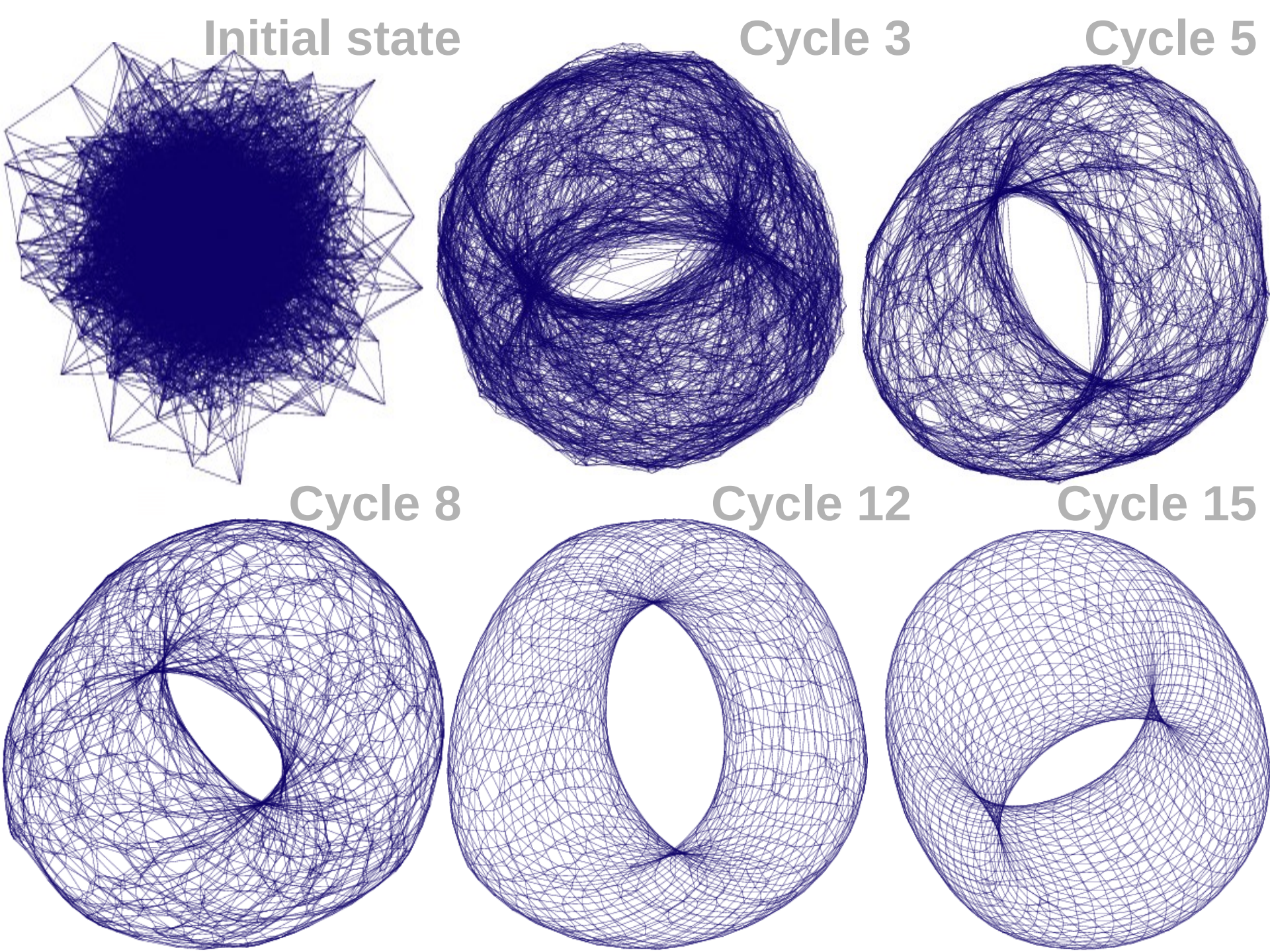
- Goal: quickly generate and maintain a random network in the face of dynamism (churn, failures, etc)
- node descriptors: contain the address and creation time of descriptor
- selectPeer: Selects a young descriptor or a random one
- update: fills the view with the youngest descriptors or with a random subset

T-Man: a gossip protocol for structured topologies

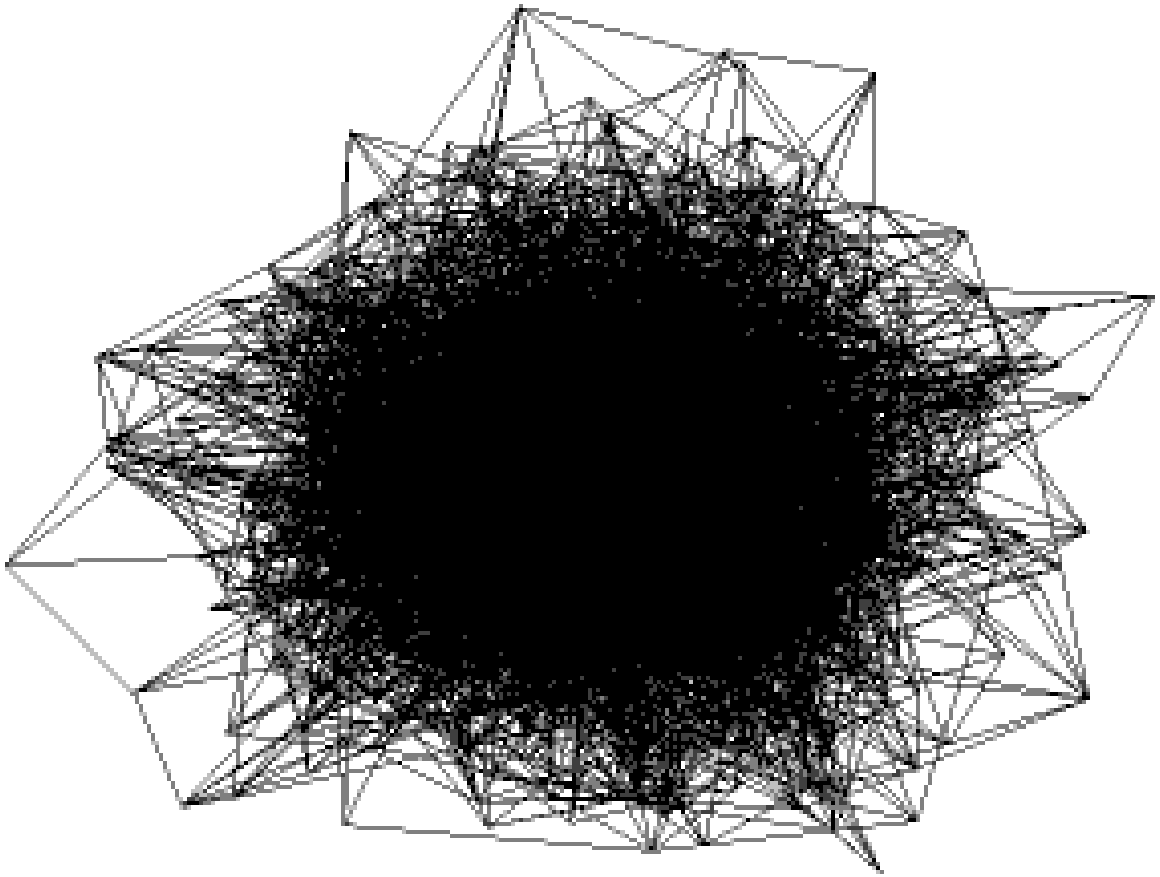
- Goal: quickly generate and maintain a
  - A very wide range of pre-specified or even dynamically specified topologies
  - In the face of dynamism (churn, failures, etc)
- node descriptors: contain the profile of the node (real number, vector, etc)
- selectPeer: Ranks view using a ranking function that defines the target topology and selects a low rank neighbor
- update: fills the view with the lowest rank descriptors

Distance based ranking functions

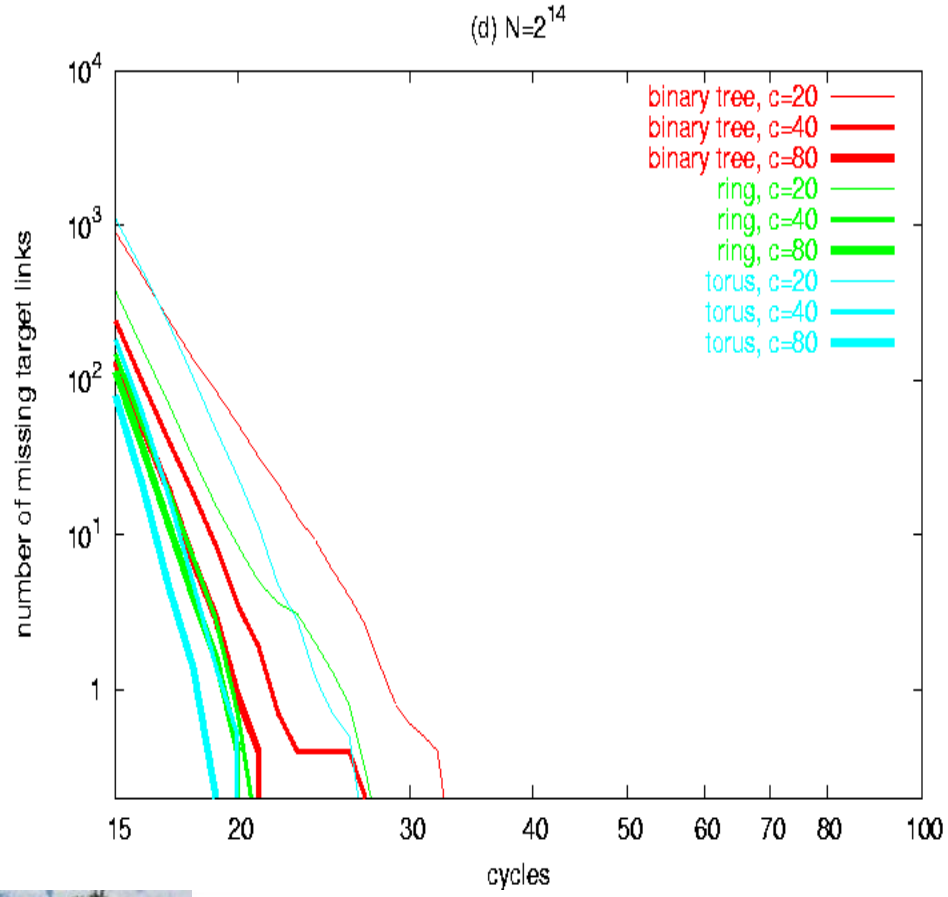
- Example 1 (ring and line): Let the nodes be real numbers. Let the ranking function be defined by the distance d(a,b)=|a-b|. For the ring, apply periodic boundary conditions, assuming nodes are from [0,N].
- Example 2 (mesh and torus): Let the nodes be two dimensional real vectors. Similarly to the ring, let the Manhattan distance define the topology

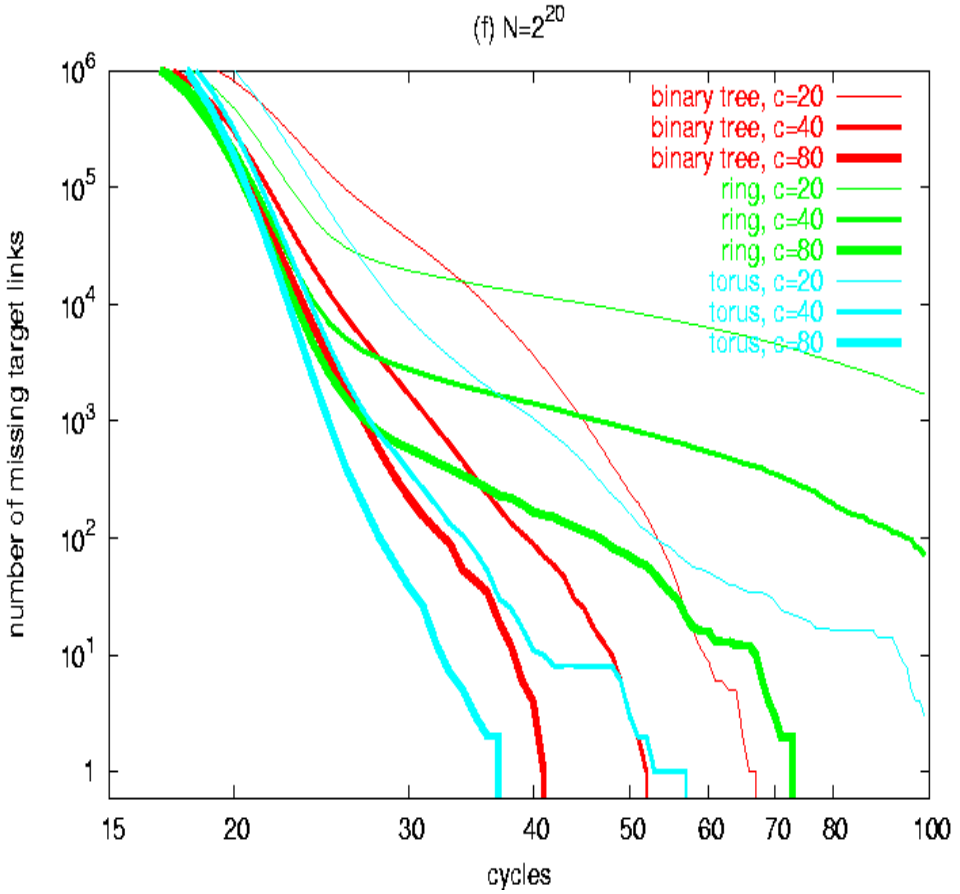

Initial state
Cycle 3
Cycle 5
Cycle 8
Cycle 12
Cycle 15

Evolution of a grid from random initial topology (15 cycles)

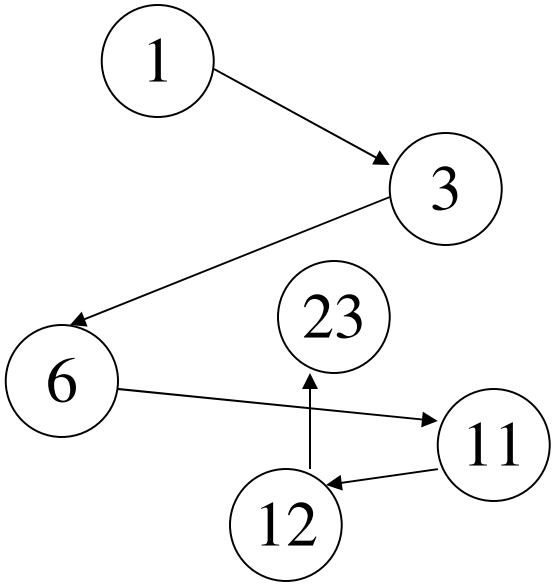


Time to reach perfect topology

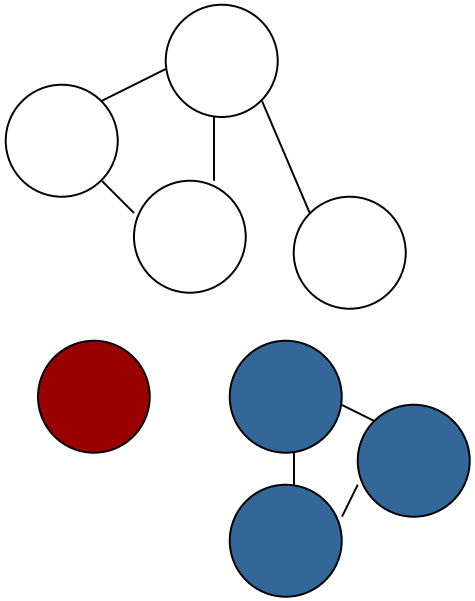




What can we bootstrapped?



Sorting



Clustering

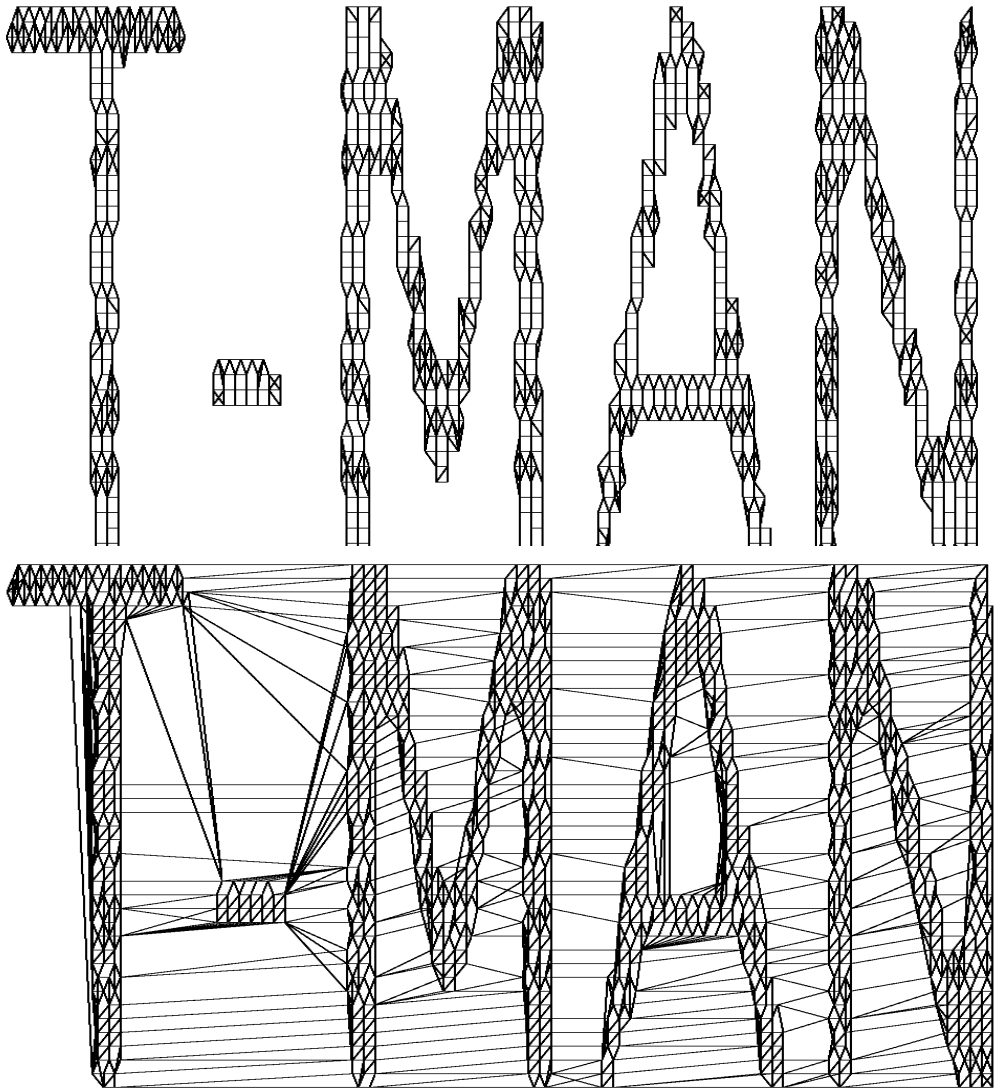
What can we bootstrapped?

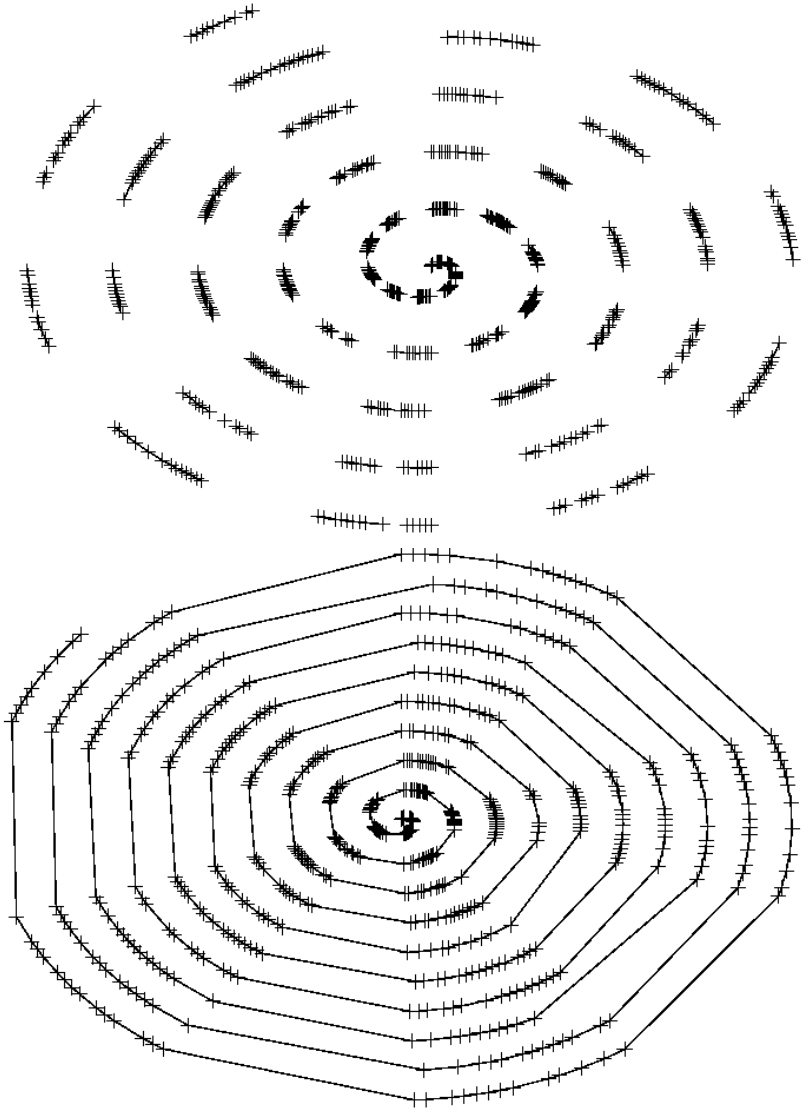
- (geographical, semantic, etc) proximity overlays
  - simply with appropriate distance function
- Distributed Hashtable routing substrates
  - typically a distance function (eg ring) and additional data collection during the process
    - ring+fingers (Chord)
    - [ring+] prefix tables (Pastry, Kademlia, etc)

Direction dependent ranking functions

- Example 4 (sorting): Let <= be a total ordering over the nodes. Let the ranking function apply a distance function consistent with <= separately to those < and > than the base node, and merge the ranked two subsets
  - For example R(10,{1,2,4,100, 300}) could return (4,100,2,300,1). No distance function over the set of nodes generates this ranking function!
- Example 5 (2d proximity): Similar to sorting, classifying nodes into four subsets, ordering them according to distance and merging them.

Illustration of clustering and sorting





Summary

- presented an architecture for managing large P2P pools of resources
- presented some protocols that implement some of the fuctionality
- the architecture so far is very simple and lightweight: mostly gossip-based protocols