Simulating overlay networks with PeerSim

Moreno Marzolla
Dipartimento di Informatica—Scienza e Ingegneria (DISI)
Università di Bologna

http://www.moreno.marzolla.name/

Acknowledgements

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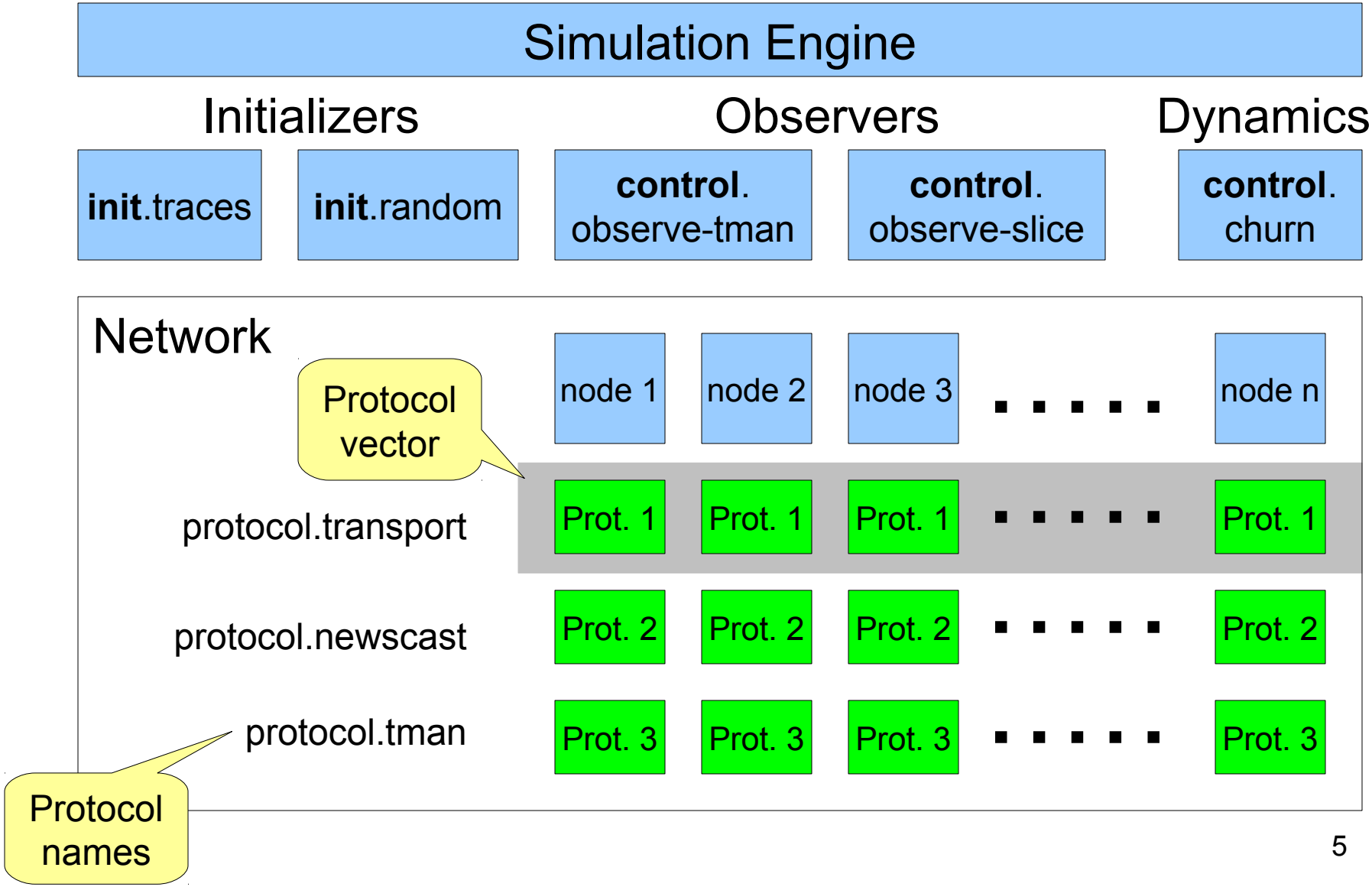
What is PeerSim?

- PeerSim is an open source P2P systems simulator developed at the Department of Computer Science, University of Bologna
- It has been developed with Java
- Available on Source Forge *(http://peersim.sf.net)*
- Its aim is to cope with P2P systems properties
- High Scalability (up to 1 million nodes)
- Highly configurable
- Architecture based on pluggable components

The peersim Simulation Engine

- Cycle-Driven (CD)
  - Quick and dirty: no messages, no transport, synchronized
  - Specialized for epidemic protocols
  - Tested up to 10^7 nodes
- Event-Driven (ED)
  - More realistic: message-based, realistic transports
  - Tested up to 2.5×10^5 nodes
  - Not considered in these lectures

Peersim


Simulation Engine
Initializers
Observers
Dynamics
init.traces
init.random
control. observe-tman
control. observe-slice
control. churn
Network
Protocol vector
node 1
node 2
node 3
node n
protocol.transport
Prot. 1
protocol.newscast
Prot. 2
protocol.tman
Prot. 3
Protocol names

Network Representation

- Network
  - global array which contains all the network nodes
- Node
  - each node's state and actions are described through a stack of protocols. Protocols are accessed through a *Pid*
- Linkable
  - interface used to access and manage node's view and other properties of a node
  - More on the Linkable interface shortly...

Network Representation

- CDProtocol: interface used to describe node's actions at each cycle.
  - A generic node can both perform local actions (CDProtocol) and manage the local view (Linkable)
- Control: performs the global initialization and performance analysis
  - Initializers are just Control objects with the peculiarity of being executed just once at the beginning

```
public interface Node extends Fallible, Cloneable
{

/**
 * Returns the <code>i</code>-th protocol in this node. If <code>i</code>
 * is not a valid protocol id (negative or larger than or equal to the number
 * of protocols), then it throws IndexOutOfBoundsException.
 */
public Protocol getProtocol(int i);

/**
 * Returns the number of protocols included in this node.
 */
public int protocolSize();

/**
* Returns the unique ID of the node. It is guaranteed that the ID is unique
* during the entire simulation, that is, there will be no different Node
* objects with the same ID in the system during one invocation of the JVM.
* Preferably nodes
* should implement <code>hashCode()</code> based on this ID.
*/
public long getID();

/* … */
}
```

```
public interface Protocol extends Cloneable
{

/**
 * Returns a clone of the protocol. It is important to pay attention to
 * implement this carefully because in peersim all nodes are generated by
 * cloning except a prototype node. That is, the constructor of protocols is
 * used only to construct the prototype. Initialization can be done
 * via {@link Control}s.
 */
public Object clone();

}
```

Main Interfaces: Protocol

- The *CDProtocol* interface is used to define cycle-driven protocols, that is the actions performed by each *node* at each simulation cycle
- Each node can run more than one protocol
- Protocols are executed sequentially

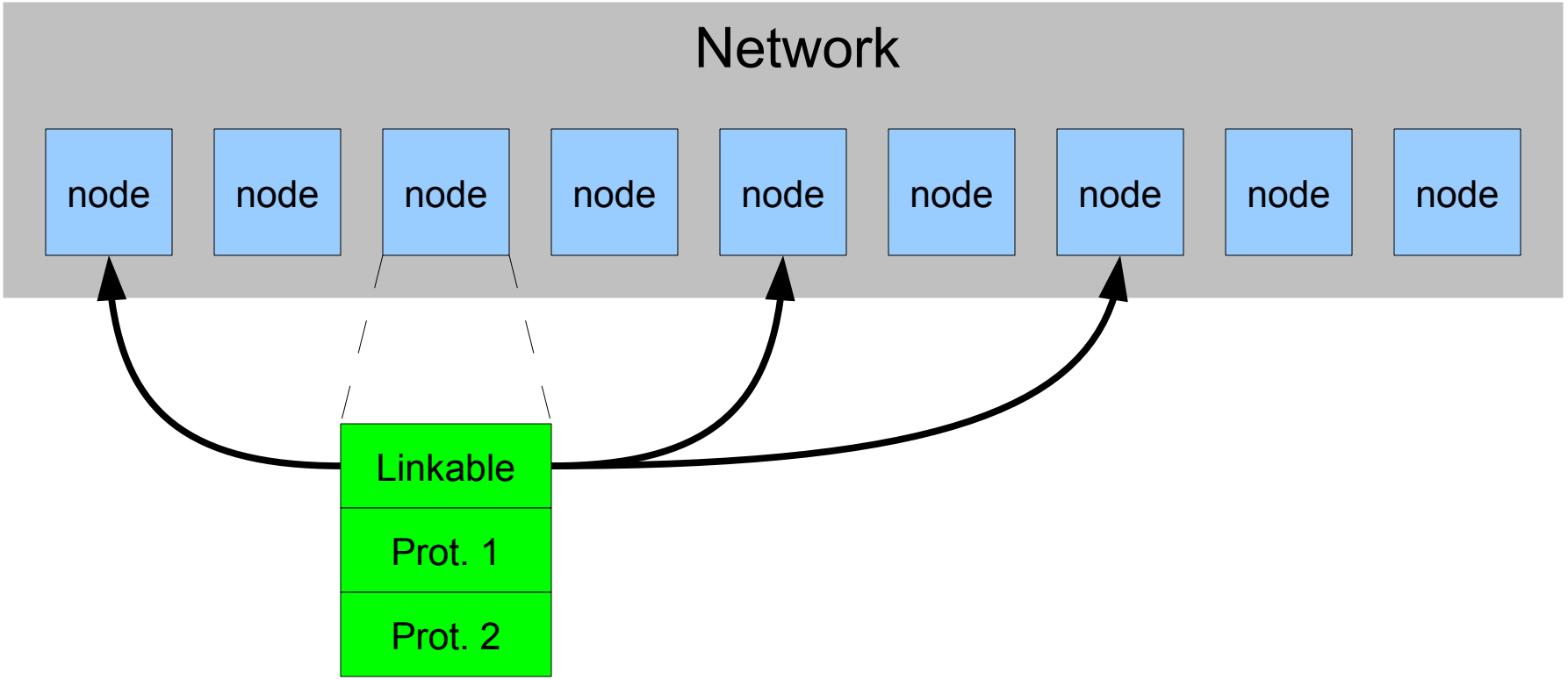
```
/**
* Defines cycle driven protocols, that is, protocols that have a periodic
* activity in regular time intervals.
*/
public interface CDProtocol extends Protocol
{

/**
 * A protocol which is defined by performing an algorithm in more or less
 * regular periodic intervals.
 * This method is called by the simulator engine once in each cycle with
 * the appropriate parameters.
 *
 * @param node
 *          the node on which this component is run
 * @param protocolID
 *          the id of this protocol in the protocol array
 */
public void nextCycle(Node node, int protocolID);

}
```

Main Interfaces: Linkable

- *Linkable* is used to manage node's view.
- Typical actions are:
  - Add neighbour
  - Get neighbour
  - Node's degree
- Note: the *Linkable* interface does **not** support nodes removal; you need to define your own interface to do so

```
public interface Linkable extends Cleanable {
        /**
        * Returns the size of the neighbor list.
        */
        public int degree();

        /**
        * Returns the neighbor with the given index.
        */
        public Node getNeighbor(int i);

        /**
        * Add a neighbor to the current set of neighbors.
        */
        public boolean addNeighbor(Node neighbour);

        /**
        * Returns true if the given node is a member of the neighbor set.
        */
        public boolean contains(Node neighbor);

        /**
        * A possibility for optimization. An implementation should try to
        * compress its internal representation. Normally this is called
        * by initializers or other components when
        * no increase in the expected size of the neighborhood can be
        * expected.
        */
        public void pack();
}
```

The Linkable interface



The Control interface

- Used to define operations that require global network knowledge and management, such as:
  - Initializers, executed at the beginning of the simulation
    - Initial topology
    - Nodes state
  - Dynamics, executed periodically during the simulation
    - Adding nodes
    - Removing nodes
    - Resetting nodes
  - Observers, executed periodically during the simulation
    - Aggregated values from all the nodes

The Control interface

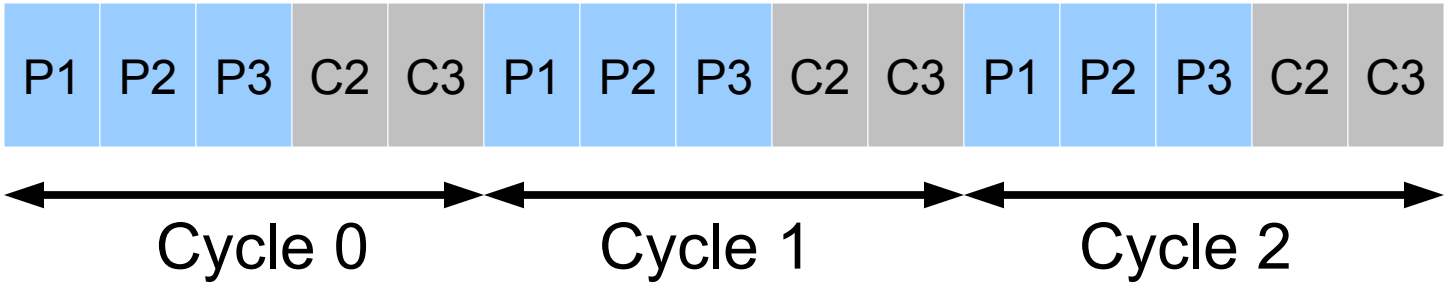
```
/**
 * Generic interface for classes that are responsible for observing or modifying
 * the ongoing simulation. It is designed to allow maximal flexibility therefore
 * poses virtually no restrictions on the implementation.
 */
public interface Control
{

/**
 * Performs arbitrary modifications or reports arbitrary information over the
 * components.
 * @return true if the simulation has to be stopped, false otherwise.
 */
public boolean execute();

}
```

CDSimulator

Pseudocode

```
for i := 1 to simulation.experiments do
    create Network
    create prototype Node :
        for i := 1 to #protocols do
                    create protocol instance
    for j := 1 to network.size do
        clone prototype Node into Network
    create controls ( initializers, dynamics, observers )
    execute initializers
    for k := 1 to simulation.cycles do
        for j := 1 to network.size do
            for p := 1 to #protocols do
                execute Network.get(j).getProtocol(p).nextCycle()
        execute controls
        if ( one control returned true ) then
            break
```

CDSimulator



Peersim Configuration

- Once all components have been implemented the whole simulation has to be set up
  - Declare what components to use
  - Define the way they should interact
- In Peersim simulations are defined through a plain text configuration file
- Configuration file is divided in 3 main parts
  - General setup
  - Protocol definition
  - Control definition

Peersim Configuration

- Plain ASCII file containing key-value pairs
  - Lines starting by # are ignored
- Syntax:

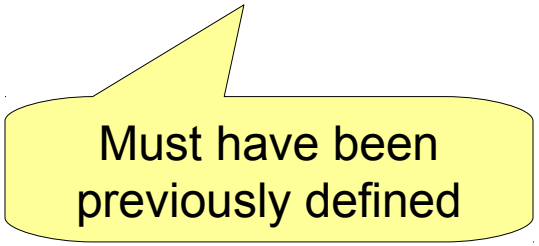
```
{protocol,init,control}.string_id
[full_path]classname
```

- The class Initializer implements the interface Control
- An Initializer object is run at the beginning of the simulation

Peersim Configuration

- Component parameters' syntax

```
{protocol,init,control}.string_id.parameter_name
parameter_value
```



Example

```
random.seed 1234567891

control.shf Shuffle

simulation.cycles 100
simulation.experiments 50

network.size 10^6
network.node peersim.core.GeneralNode
```

Global property: used to initialize the RNG

Shuffles the order in which nodes are visited at each cycle

Maximum number of simulation cycles

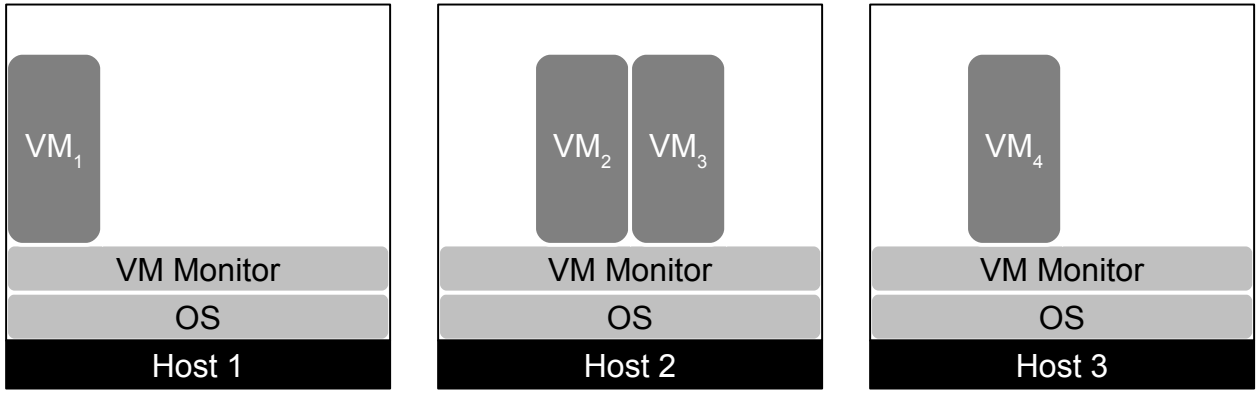
Number of nodes in the network

V-MAN

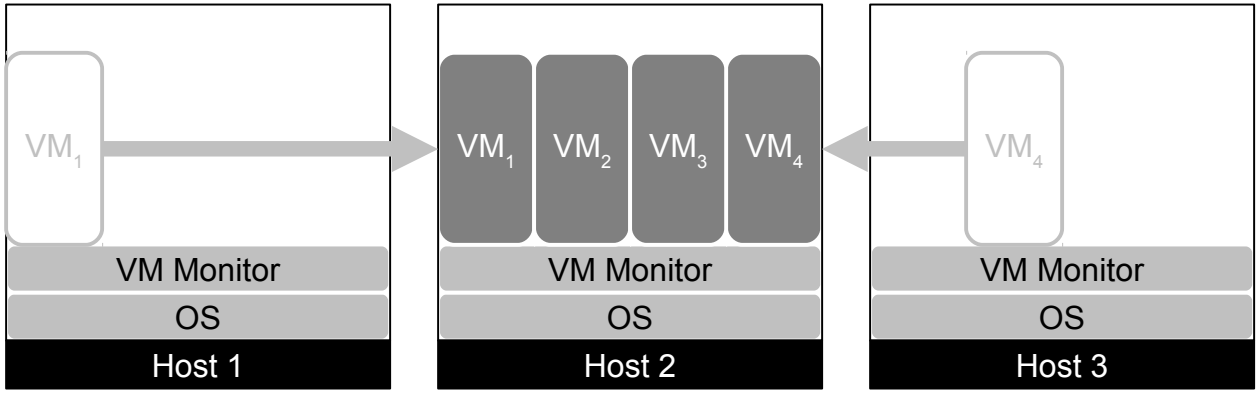
Goal

- Reduce power consumption in Cloud infrastructures
- Idea
  - Migrate Virtual Machines away from lightly loaded servers
  - Servers running no VM can be put to sleep

V-MAN—Example



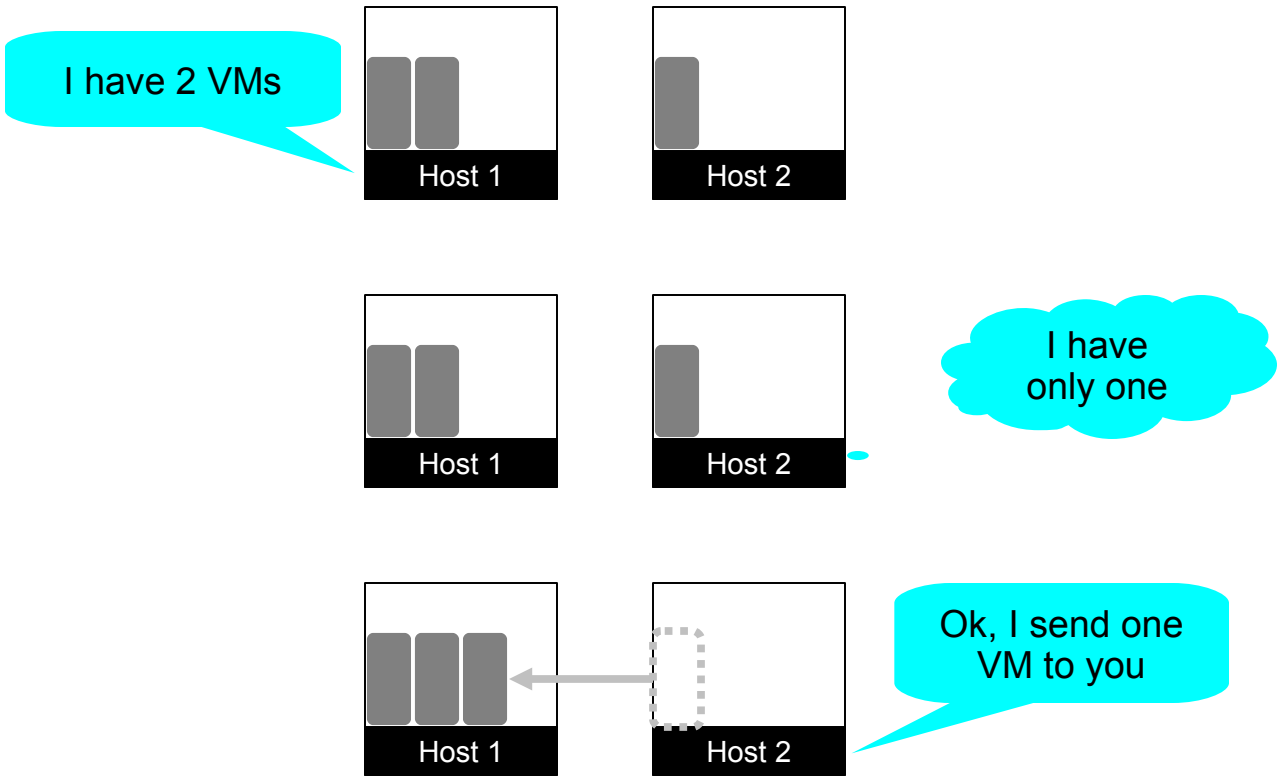
(a) Before consolidation



(b) After consolidation of VM_1 and VM_4 to host 2

V-MAN—Example

- Server consolidation is implemented using a simple gossip protocol (a variant of *aggregation*)



V-MAN

- Each node *i* maintains the number H_i of VM it is currently running
  - All nodes have a maximum capacity C
- Node *i* select random peer *j*:
  - If $H_i \leq H_j \rightarrow$ node *i* sends its VMs to node *j*
  - If $H_i > H_j \rightarrow$ node *i* receives VMs from node *j*

RandomDistributionInitializer

- Initially, each node is assigned a random number of VMs
- This is done by the RandomDistributionInitializer

```
public class RandomDistributionInitializer implements Control,NodeInitializer {

    // … constants and local variables omitted …

    /**
     * This class provides a simple random distribution in a bounded
     * interval defined by parameters {@link #PAR_MIN} and {@link #PAR_MAX}.
     */
    public boolean execute() {
        int tmp;
        for (int i = 0; i < Network.size(); ++i) {
            initialize( Network.get(i) );
        }
        return false;
    }

    /**
     * Initialize a single node by allocating a random number of virtual
     * machines, defined by parameters {@link #PAR_MIN} and {@link #PAR_MAX}.
     */
    public void initialize(Node n) {
        int tmp = min + CommonState.r.nextInt( max-min+1 );
        ((SingleValue) n.getProtocol(protocolID)).setValue(tmp);
    }
}
```

BasicConsolidation

- This class implements the CDProtocol interface
  - V-MAN is actually implemented here
- BasicConsolidation also inherits from SingleValueHolder
  - The value held in each node is the current number of running VMs

```
public class BasicConsolidation extends SingleValueHolder implements CDProtocol
{
    /**
     * Node capacity. The capacity is the maximum number of
     * Virtual Machines that a node can host. Defaults to 1.
     *
     * @config
     */
    protected static final String PAR_CAPACITY = "capacity";

    /** Capacity. Obtained from config property {@link #PAR_CAPACITY}. */
    private final int capacity_value;

    /**
     * Standard constructor that reads the configuration parameters. Invoked by
     * the simulation engine.
     *
     * @param prefix
     *            the configuration prefix for this class.
     */
    public BasicConsolidation(String prefix) {
        super(prefix);
        // get capacity value from the config file. Default 1.
        capacity_value = (Configuration.getInt(prefix+"."+PAR_CAPACITY, 1));
    }
```

```
/**
 * Using an underlying {@link Linkable} protocol
 * performs a consolidation step with all neighbors of the node
 * passed as parameter.
 *
 * @param node
 *            the node on which this component is run.
 * @param protocolID
 *            the id of this protocol in the protocol array.
 */
public void nextCycle(Node node, int protocolID) {
    int linkableID = FastConfig.getLinkable(protocolID);
    Linkable linkable = (Linkable) node.getProtocol(linkableID);

    for (int i = 0; i < linkable.degree(); ++i) {
        Node peer = linkable.getNeighbor(i);
        // The selected peer could be inactive
        if (!peer.isUp())
            continue;
  BasicConsolidation n = (BasicConsolidation) peer.getProtocol(protocolID);
        doTransfer(n);
    }
}
```

```
/**
 * Performs the actual consolidation selecting to make a PUSH or PULL
 * approach. The idea is to send the maximum number of VMs from
 * the node with fewer VMs to the other one.
 *
 * @param neighbor
 *            the selected node to talk with.
 */
protected void doTransfer(BasicConsolidation neighbor) {
    int a1 = (int)this.value;
    int a2 = (int)neighbor.value;
    if ( a1 == 0 || a2 == 0 ) return;
    int a1_avail = capacity_value - a1;
    int a2_avail = neighbor.capacity_value - a2;
    int trans = Math.min( Math.min(a1,a2),
                          Math.min(a1_avail, a2_avail) );
    if (a1 <= a2) {
        // PUSH
        a1 -= trans;
        a2 += trans;
    } else {
        // PULL
        a1 += trans;
        a2 -= trans;
    }
    assert( a1 >= 0 && a1 <= capacity_value );
    assert( a2 >= 0 && a1 <= capacity_value );
    this.value = (float)a1;
    neighbor.value = (float)a2;
}
```

VMObserver

- This class implements the Control interface
- It is used to print to standard output the number of servers with exactly *k* VMs, for all *k* = 0, … *C*

```
public class VMObserver implements Control {

    private static final String PAR_PROT = "protocol";
    private final String name;
    private final int pid;

    public VMObserver(String name) {
        this.name = name;
        pid = Configuration.getPid(name + "." + PAR_PROT);
    }

    public boolean execute() {
        IncrementalFreq freqs = new IncrementalFreq();
        long time = peersim.core.CommonState.getTime();
        int capacity = 0;
        for (int i = 0; i < Network.size(); i++) {
            BasicConsolidation protocol = (BasicConsolidation)
Network.get(i).getProtocol(pid);
            capacity = protocol.getCapacity();
            freqs.add((int)protocol.getValue());
        }
        System.out.print(name + ": " + time);
        for (int j=0; j<=capacity; ++j )
            System.out.print(" " + freqs.getFreq(j));
        System.out.println();
        return false;
    }
```

Configuration file

```
simulation.cycles 20
simulation.experiments 10
network.size 10000
WIREK 20
CORES 8

random.seed 1234567890

protocol.lnk example.newscast.SimpleNewscast
protocol.lnk.cache WIREK
protocol.vman example.vman.BasicConsolidation
protocol.vman.capacity CORES
protocol.vman.linkable lnk

init.rnd WireKOut
init.rnd.protocol lnk
init.rnd.k WIREK

init.ld example.vman.RandomDistributionInitializer
init.ld.protocol vman
init.ld.min 0
init.ld.max CORES

include.init rnd ld

control.shf Shuffle
control.vmo example.vman.VMObserver
control.vmo.protocol vman
```

General settings

Protocols settings

Controls settings

Config File: *General Settings*

```
simulation.cycles 20
simulation.experiments 10
network.size 10000
WIREK 20
CORES 8

random.seed 1234567890
```

- Each simulation is executed for 20 steps
- Perform 10 independent simulation runs
- The network has 10000 nodes
- WIREK and CORES are constants
- The seed for the random number generator is initialized with a specific value (otherwise, it is initialized with a random number)

Config File: *Protocol Settings*

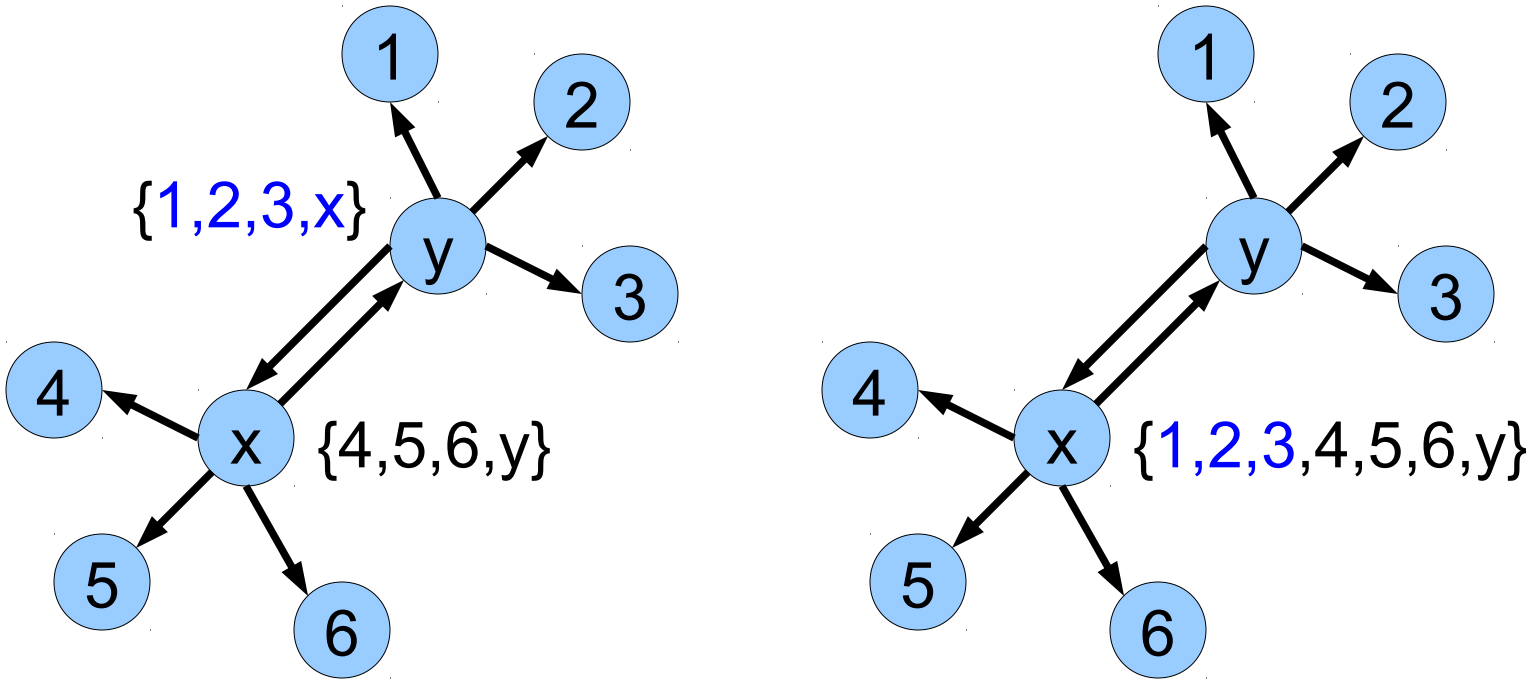
```
protocol.lnk example.newscast.SimpleNewscast
protocol.lnk.cache WIREK
protocol.vman example.vman.BasicConsolidation
protocol.vman.capacity CORES
protocol.vman.linkable lnk
```

- Protocol "*lnk*" is NewsCast
- The view size is set to the constant WIREK
- Protocol "*vman*" is V-MAN
- Each node can support at most CORES VMs
- The local view is maintained by protocol "*lnk*"

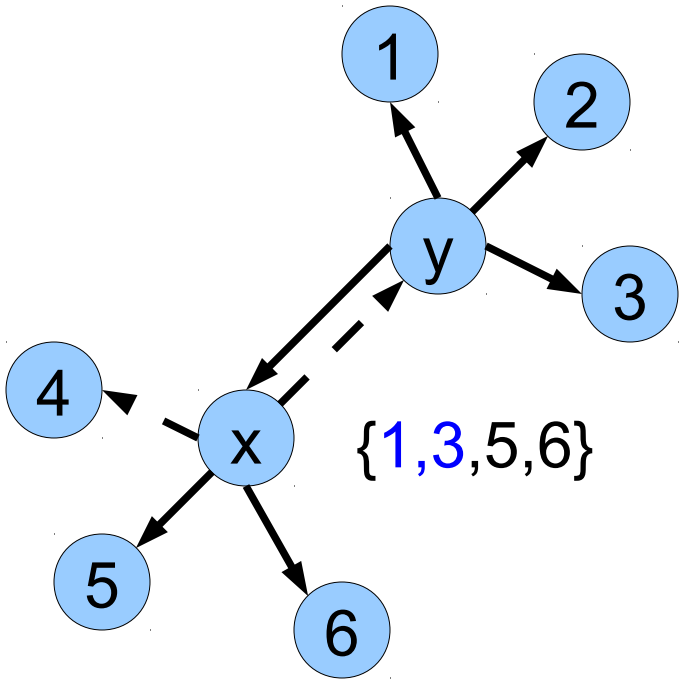
Newscast

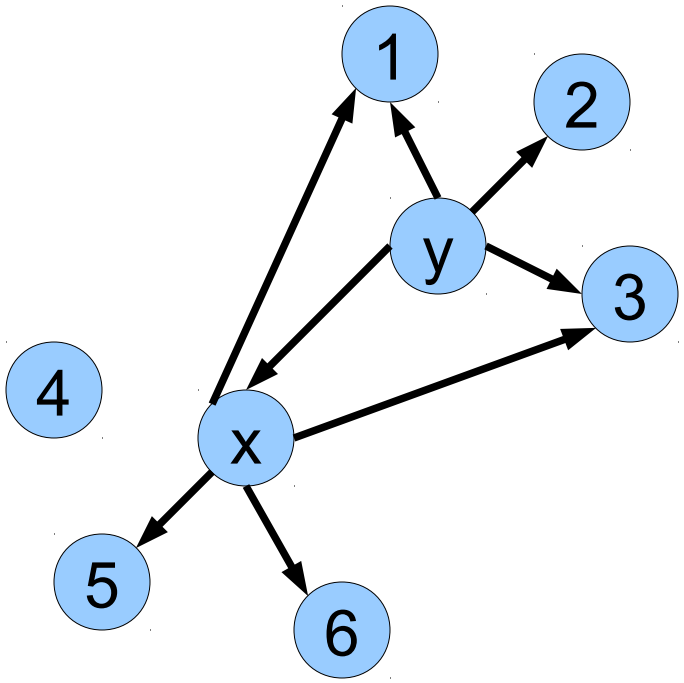
- Each node maintains a *local view*
  - Set of nodes it is connected to
- At each step, neighbors exchange their local views
- Each node merges the remote view with its local one, discarding old entries and keeping fresh ones

Newscast



Newscast





Config File: *Control Settings*

```
init.rnd WireKOut
init.rnd.protocol lnk
init.rnd.k WIREK

init.ld example.vman.RandomDistributionInitializer
init.ld.protocol vman
init.ld.min 0
init.ld.max CORES

include.init rnd ld

control.shf Shuffle
control.vmo example.vman.VMObserver
control.vmo.protocol vman
```

- Initially, build a random graph by wiring each node to *WIREK* other random nodes
- RandomDistributionInitializer assigns a random number in [0, … *CORES*] of VMs to each node

Additional resources

- PeerSim Web Page
  http://peersim.sf.net/
- Class documentation
  http://peersim.sourceforge.net/doc/index.html
- Tutorial for the Cycle-based engine
  http://peersim.sourceforge.net/tutorial1/tutorial1.pdf