Introduction to Distributed Computing Algorithms

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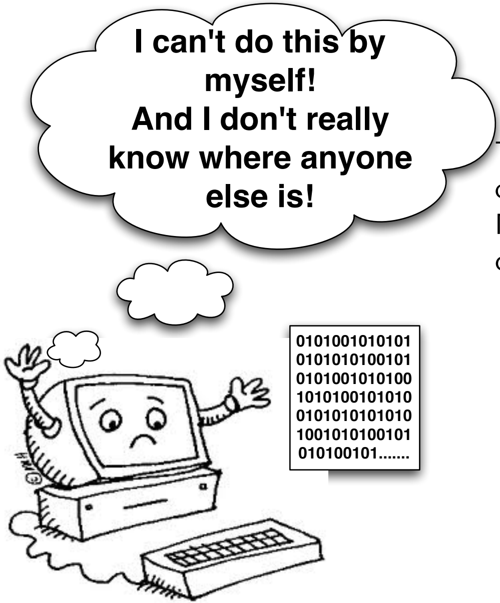
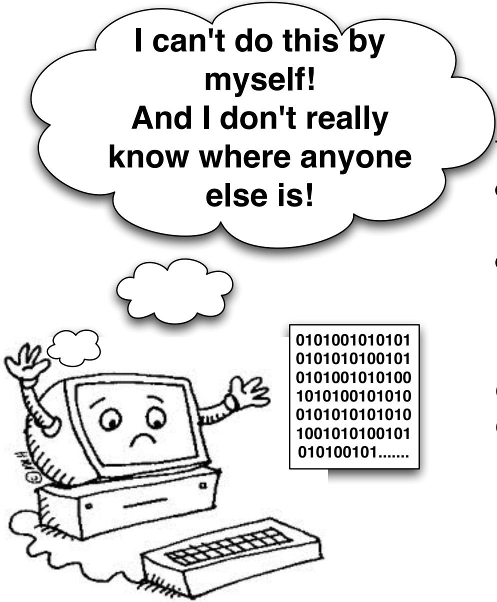
November 19, 2011

Many Unorganized Computers



Too much data processing for one computer.
Not part of an organized cluster.

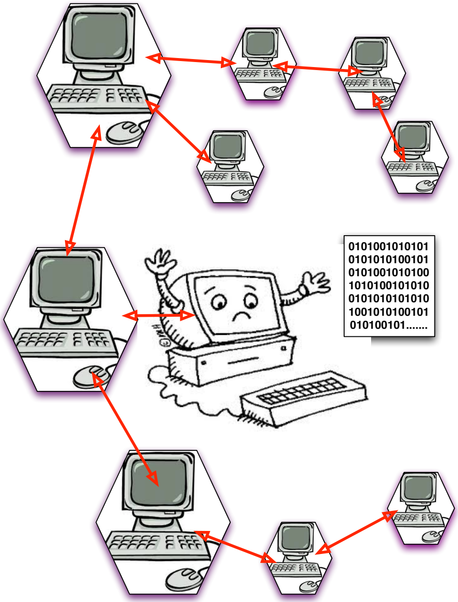
Many Unorganized Computers



Too much data processing for one computer.
Not part of an organized cluster.

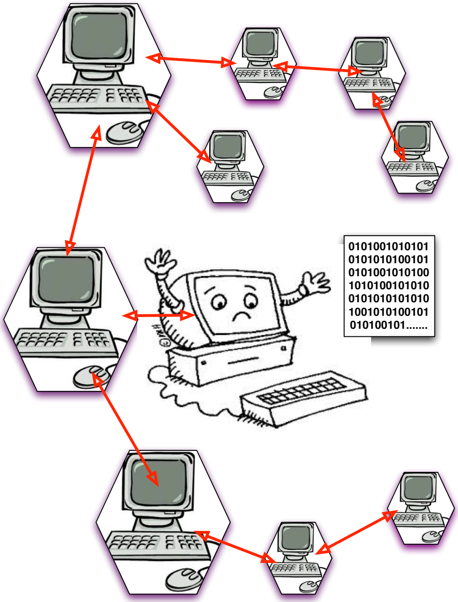
Could be huge job.
Could be small computer.

Many Unorganized Computers



Distribute computation out to friends.

Many Unorganized Computers



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Why won't this work?

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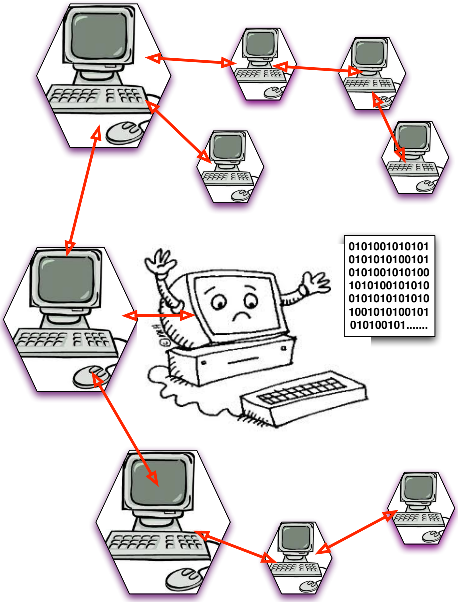
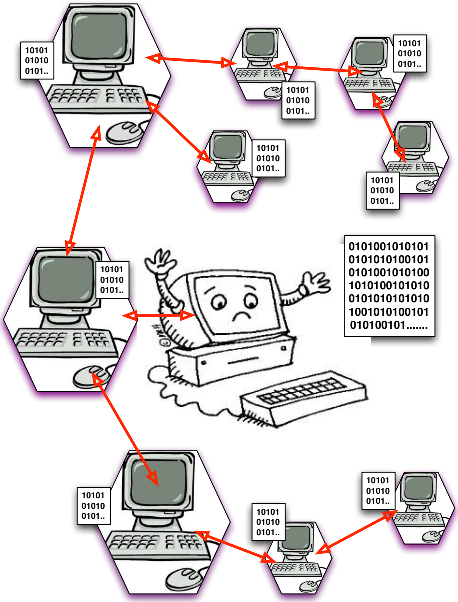


Distribute computation out to friends.
Why won't this work?

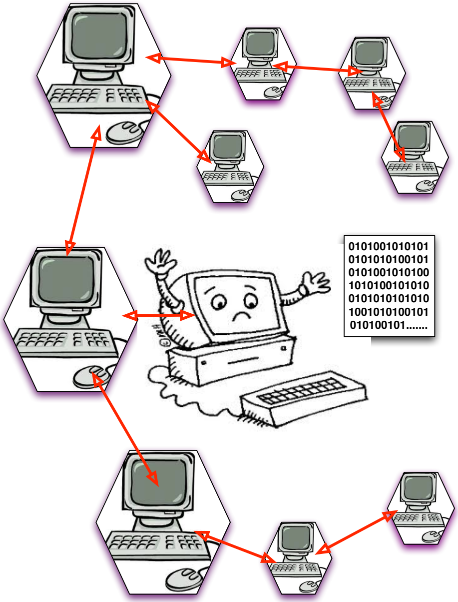
Transferring big data very expensive!
Often more expensive than computation!

Many Unorganized Computers



Goal:
Minimize Communication!

Many Unorganized Computers



Distribute computation out to friends.
When might this work?

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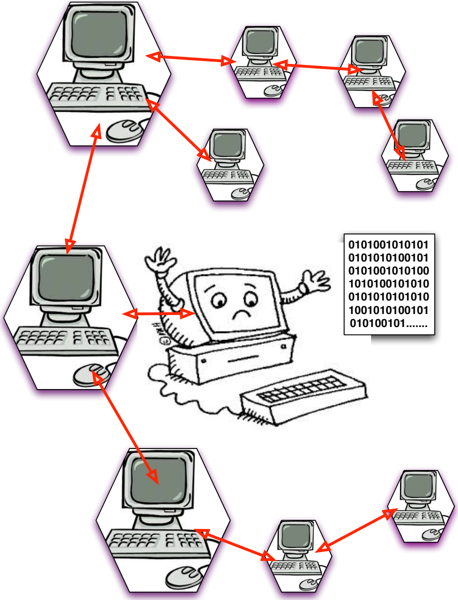
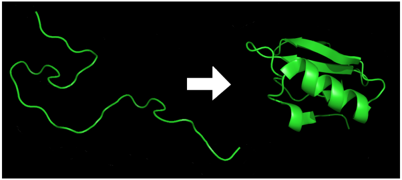


Distribute computation out to friends.
When might this work?

Computation is Very Expensive. (Exponential)

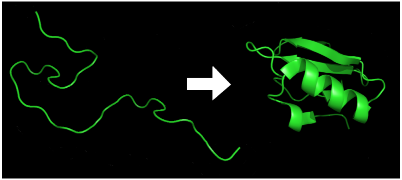
Folding@Home



Molecular dynamics

- typically very sequential
- many inaccurate and average
- explore different scenarios

Folding@Home



Molecular dynamics

- typically very sequential
- many inaccurate and average
- explore different scenarios

Central Server: sends out **work units**.
Nodes have fixed time to complete.
Failures lead to shorted jobs.

Folding@Home

How large is it?

- 439,000 CPUs
- 37,000 GPUs
- 21,000 PS3s

6.7 petaFLOPS

Molecular dynamics

- typically very sequential
- many inaccurate and average
- explore different scenarios

Central Server: sends out **work units**.
Nodes have fixed time to complete.
Failures lead to shorted jobs.

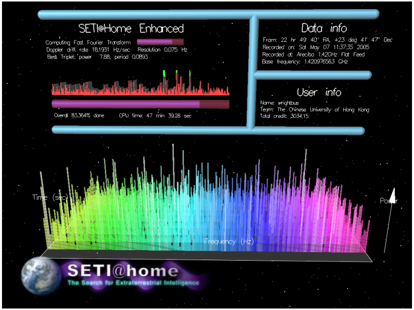
BOINC

Berkeley Open Infrastructure for Network Computing

SETI@Home

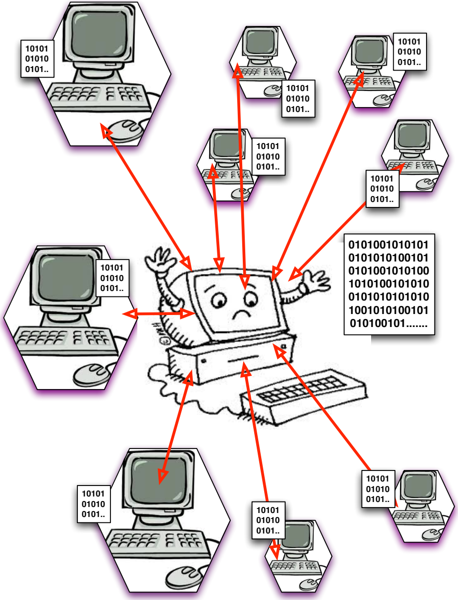
- 451,000 CPUs

5.6 petaFLOPS



More restrictive protocol than Folding@Home.
Checks results, and often duplicates.

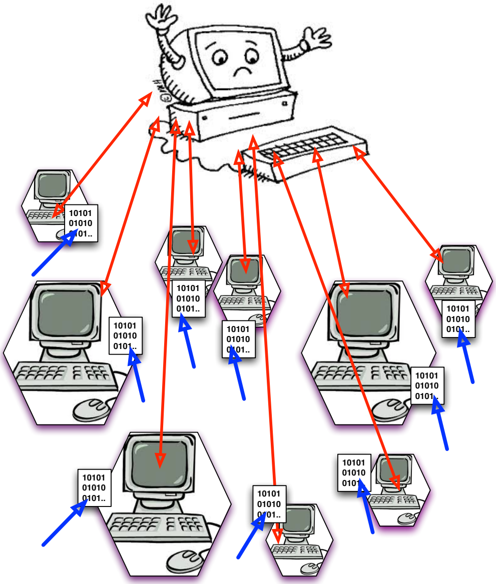
Flat Model



Each processor is connected to server.

- two-way communication.
- sometimes, data can originate on processor
- can stream in, or static
- server can be overloaded

Flat Model



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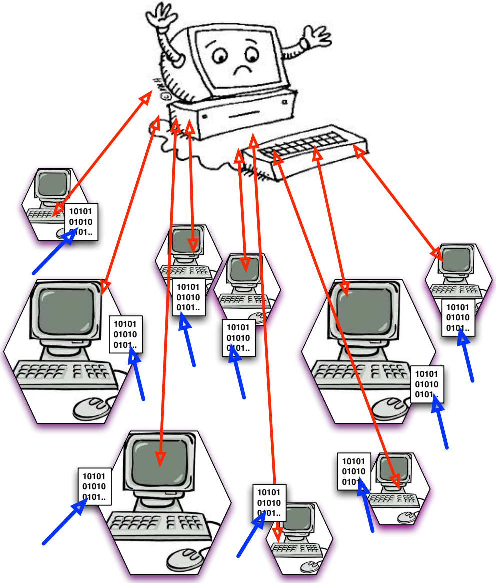
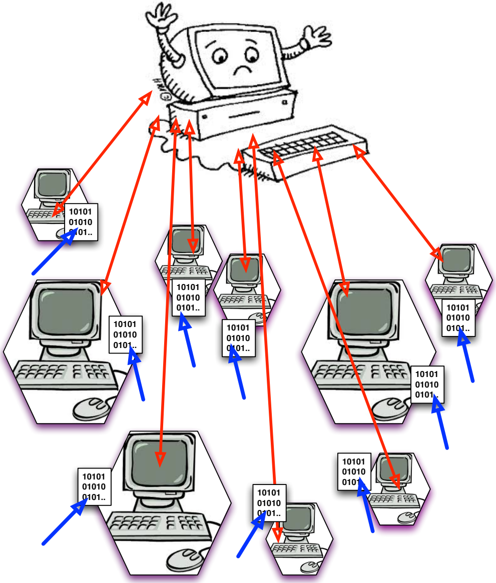
Random Sampling



Random Sample t items from k sites.
$O(k+t)$ communication.

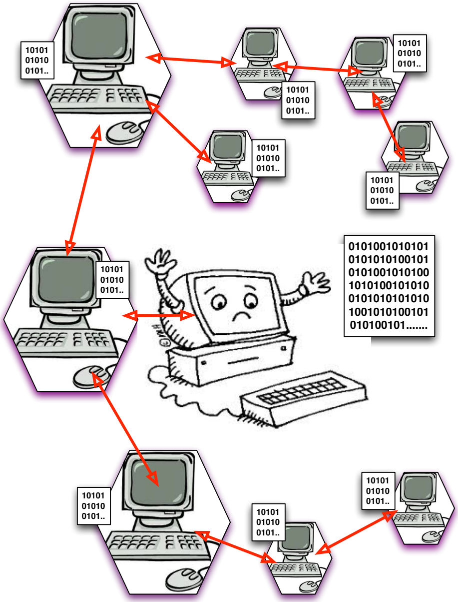
Random Sampling



Random Sample t items from k sites.
$O(k+t)$ communication.

1. Each node assigns a random variable u_i to all its data v_i.
2. Sends top value u_i to server as (x_i, u_i).
3. Server keeps x_i with top u_i
4. Asks corresponding node for next top value.
5. Go to 3.

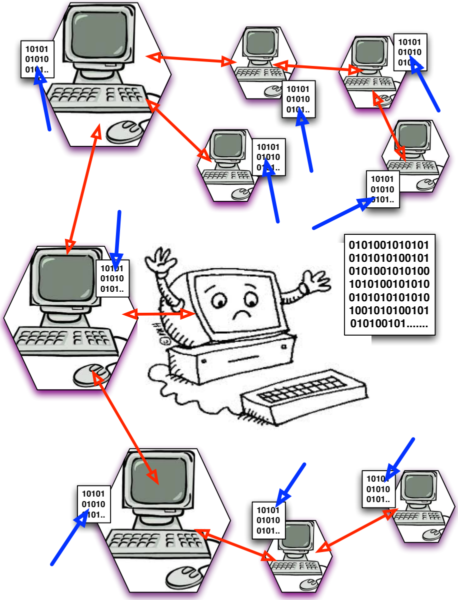
Tree Model



Many processors connected to server through tree

- two-way communication.
- arbitrary topology (tree)

Tree Model



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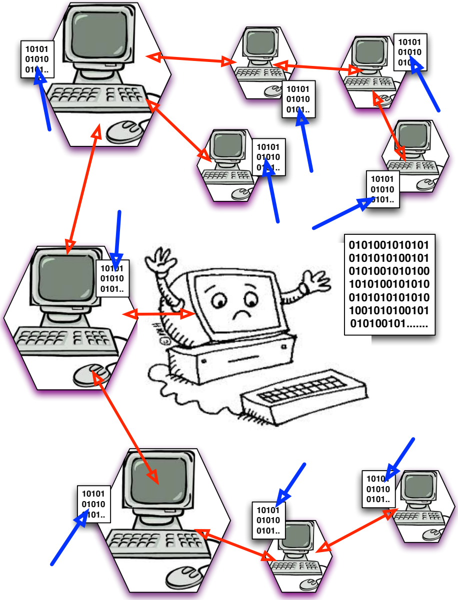

Many processors connected to server through tree

- two-way communication.
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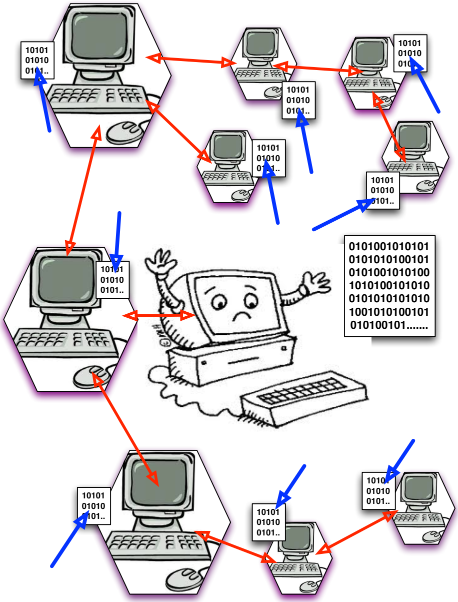
- less stress on server
- latency slower
- might multi-cast from server
- sometimes only pass summaries

Mergeable Summaries



Aggregation Network

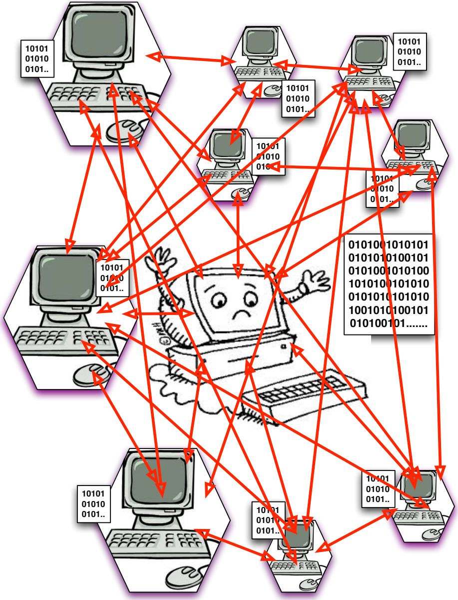
- Each node i has data X_i
- Creates summary $S_i = \sigma(X_i)$
- has ε-error, size $f(\varepsilon)$

Can merge two summaries:

- $S = \mu(S_1, S_2)$
- has ε-error on $S_1 \cup S_2$
- size $f(\varepsilon)$

Neither error nor size grows.
Can be used like **sum** or **max**.

Clique Model



Many computers, all can talk (internet)

- may limit degree (10000+ nodes)
- central server may control

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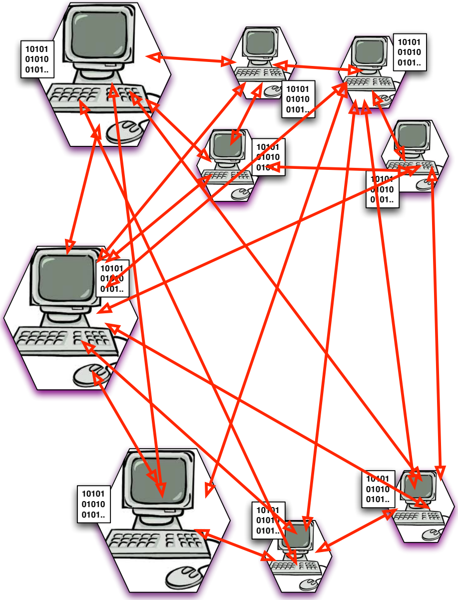

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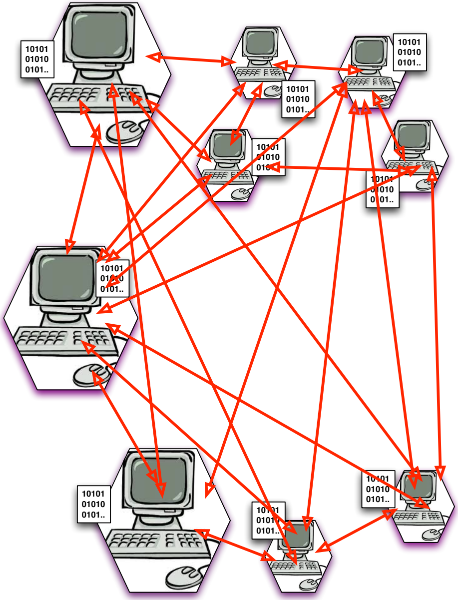

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Distributed Hash Tables

- Stores data distributed (like GFS)
- Distribute files (Bitorrent)

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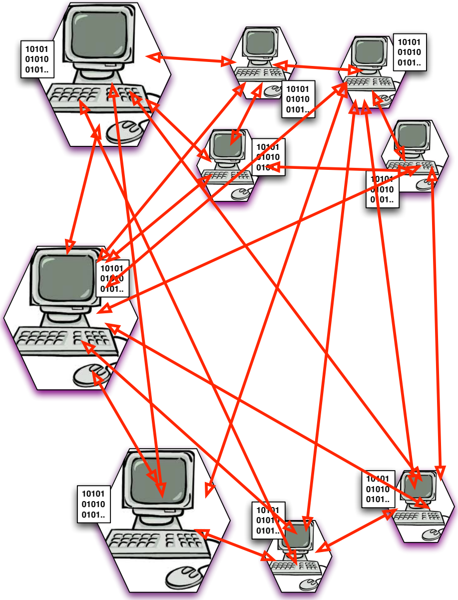

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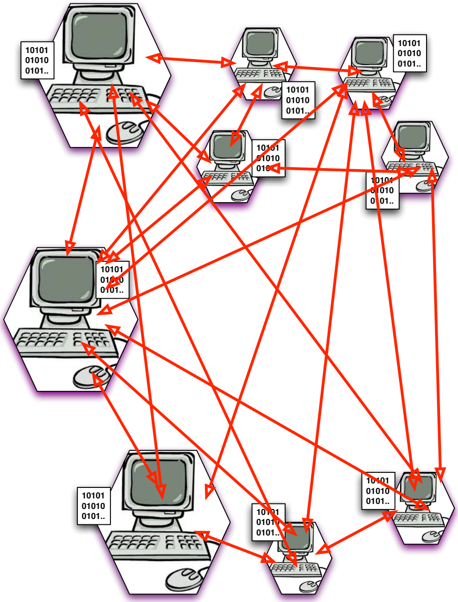
Minimize communication tolerate failure

Lower Bounds



- k computers: i
- each computer has n bits: X_i

Compute $f(X_1, X_2, \ldots, X_k)$.

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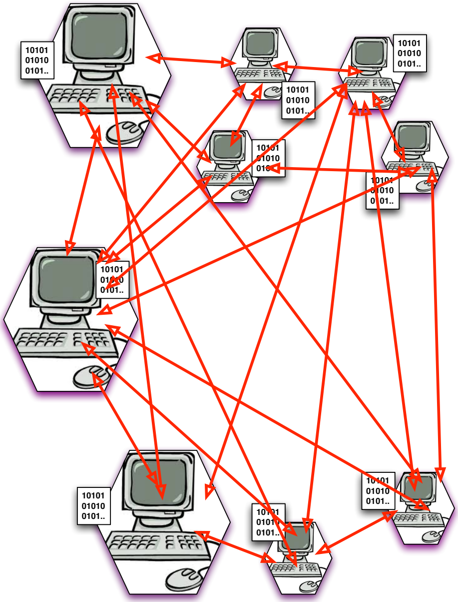

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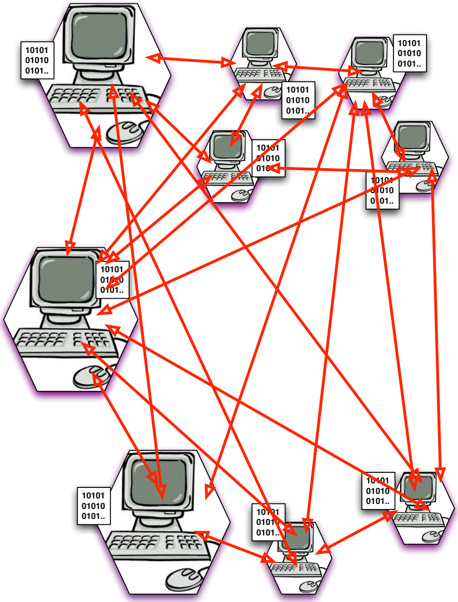

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Blackboard

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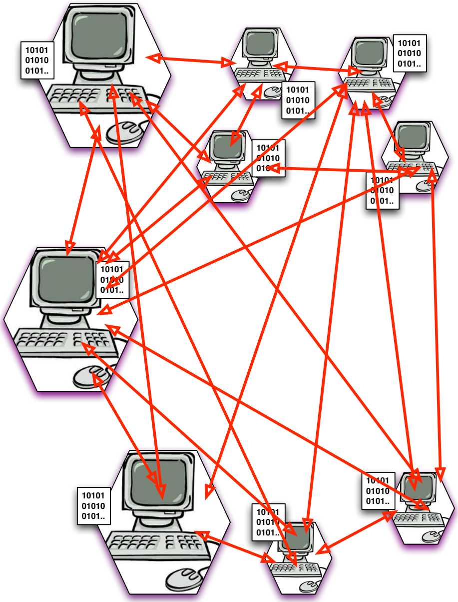

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Multi-Party

- All-pair
- $f = \{\mathrm{OR}, \mathrm{XOR}, \ldots\}$ $\Omega(nk)$ comm