

Architectures for Big Data

Peer-to-peer (P2P) data management

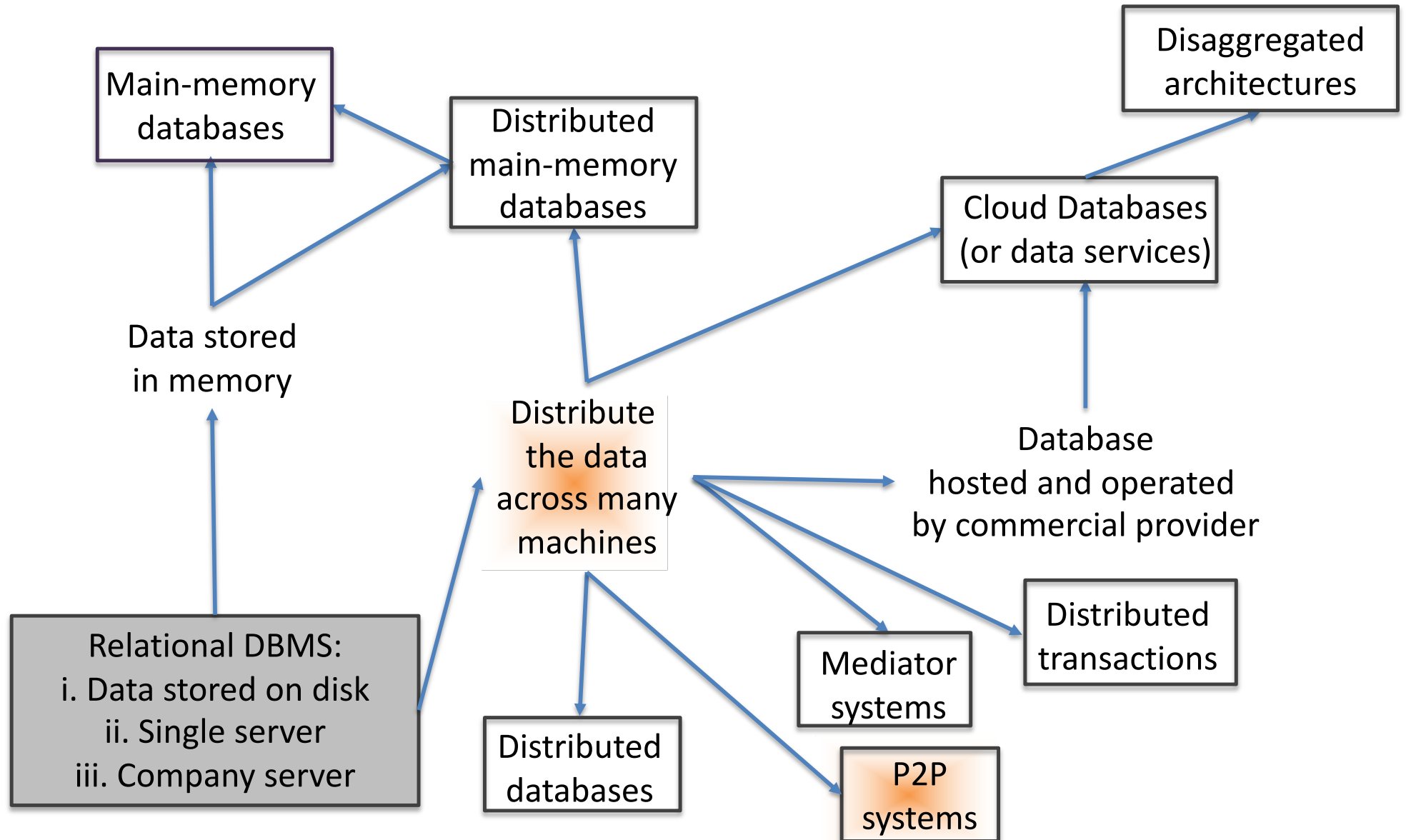
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From databases to Big Data



Peer-to-peer architectures

- Idea: easy, **large-scale** sharing of data with **no central point of control**
- All the peers play identical roles
- Peers may join the peer network or leave it at any time

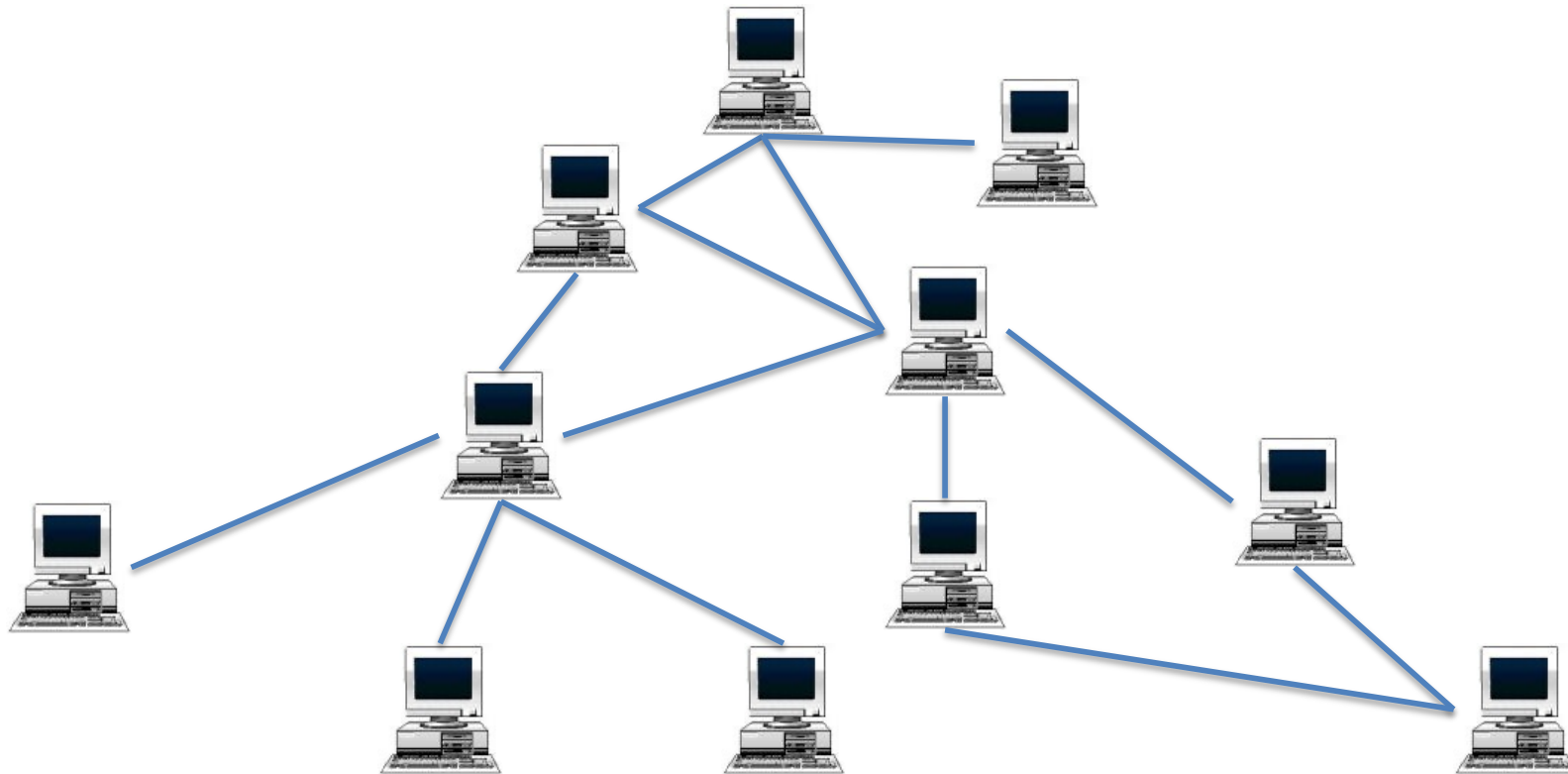
- **Advantages:**
 - Distribute work; preserve peer independence
- **Disadvantages:**
 - Lack of control over peers which may leave or fail → need for mechanisms to cope with peers joining or leaving (*churn*)
 - Schema unknown in advance; need for data discovery

Peer-to-peer architectures

- **Large-scale** sharing of data with **no central point of control**
- Two main families of P2P architectures:
 - **Unstructured** P2P networks
 - Each peer is free to connect to other peers;
 - Variant: super-peer networks
 - **Structured** P2P networks
 - Each peer is connected to a set of other peers determined by the system
- Also: hybrid P2P architectures
 - A "central" subset of the network is structured, the rest is unstructured

Unstructured P2P networks

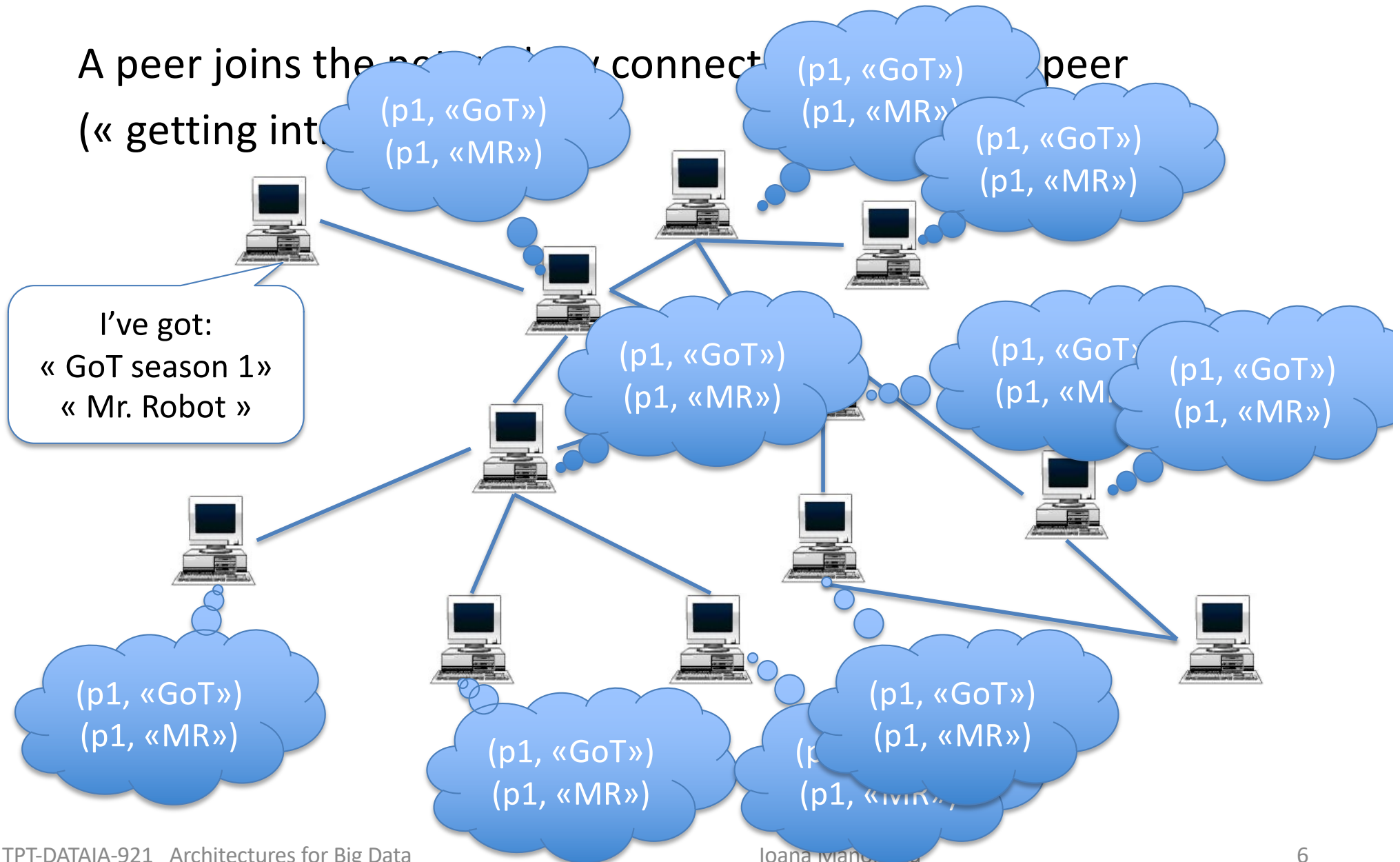
A peer joins the network by connecting to another peer
(« getting introduced »)



Each peer may advertise data that it publishes → peers « know their neighbors » up to some level

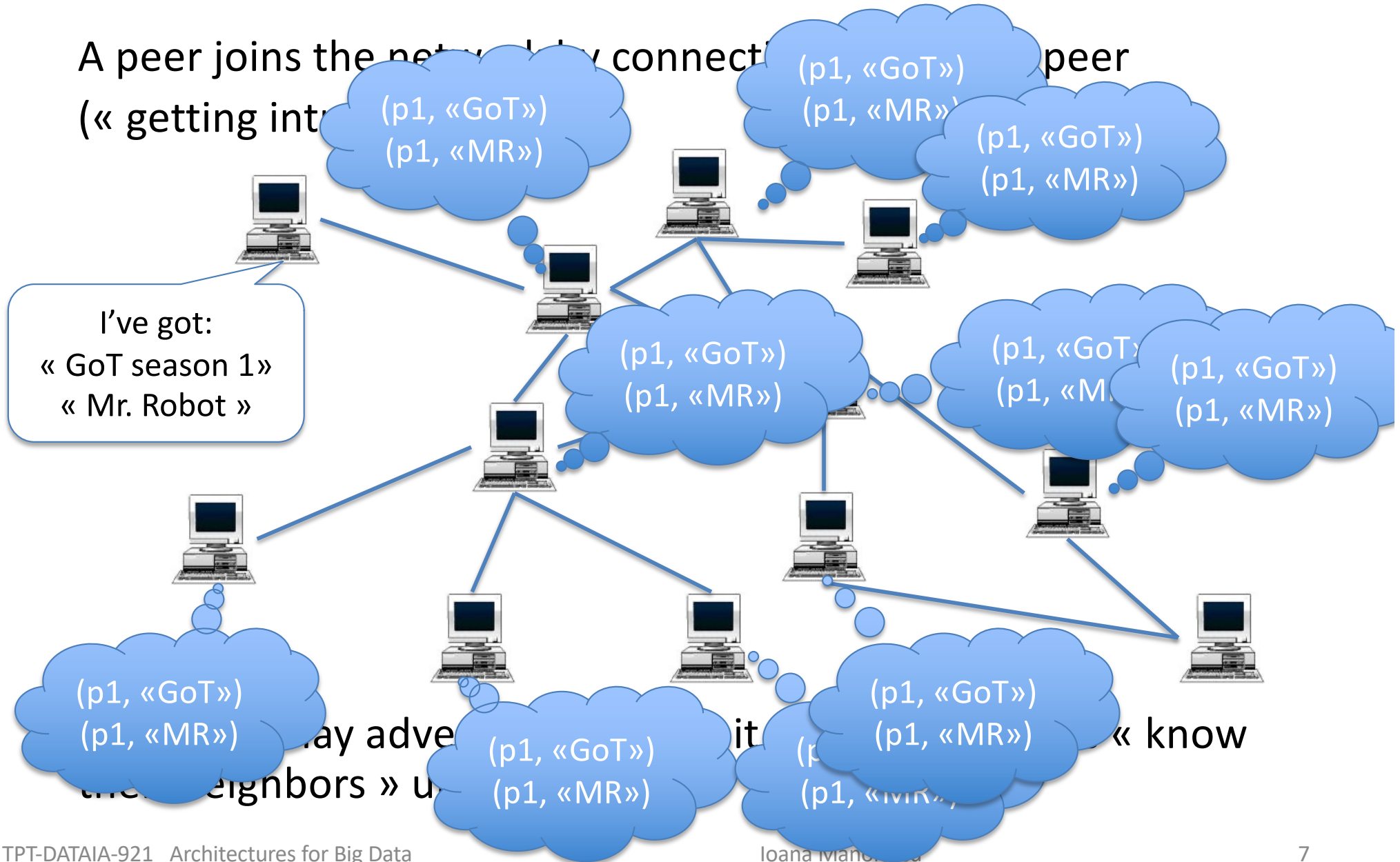
Unstructured P2P networks

A peer joins the network by connecting to a peer (« getting into the network »)



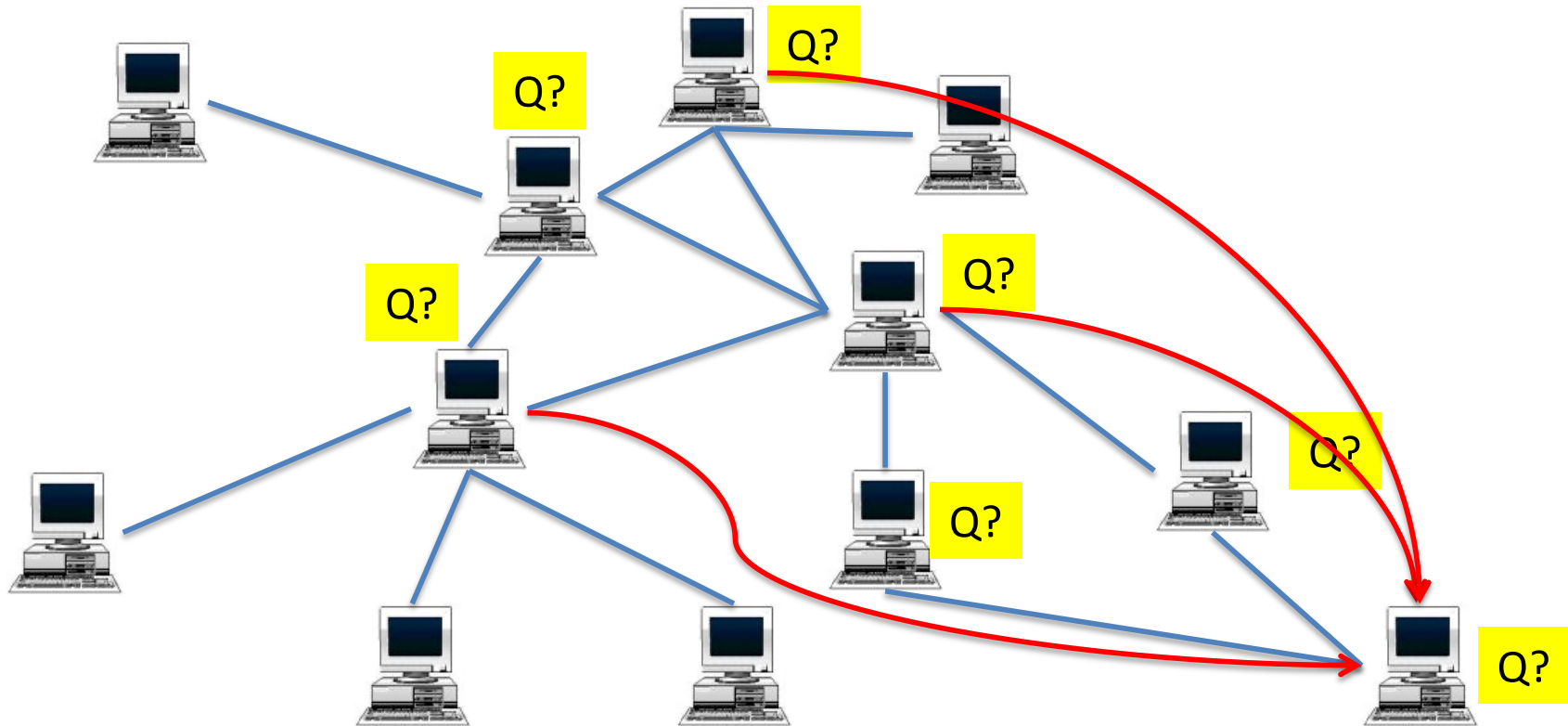
Unstructured P2P networks

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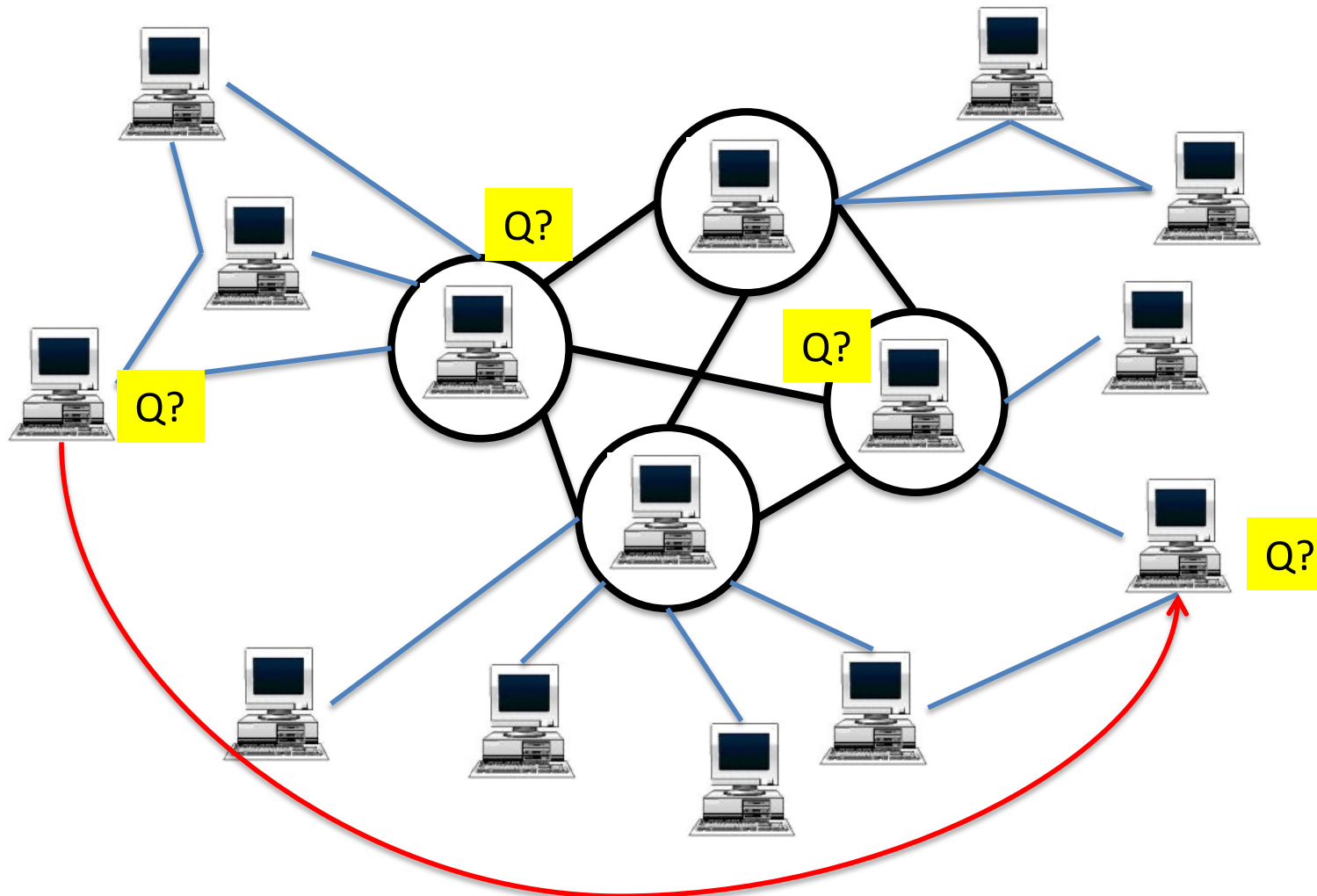
Unstructured P2P networks

Queries are evaluated by propagation from the query peer to its neighbors and so on recursively (flooding)



To avoid saturating the network, queries have TTL (time-to-live)
This may lead to missing answers → a. replication; b. superpeers

Hybrid P2P network



- Small subset of superpeers all connected to each other
- Specialized by data domain, e.g. [Aa—Bw], [Ca—Dw], ... or by address space
- Each peer is connected at least to a superpeer, which routes the peer's queries

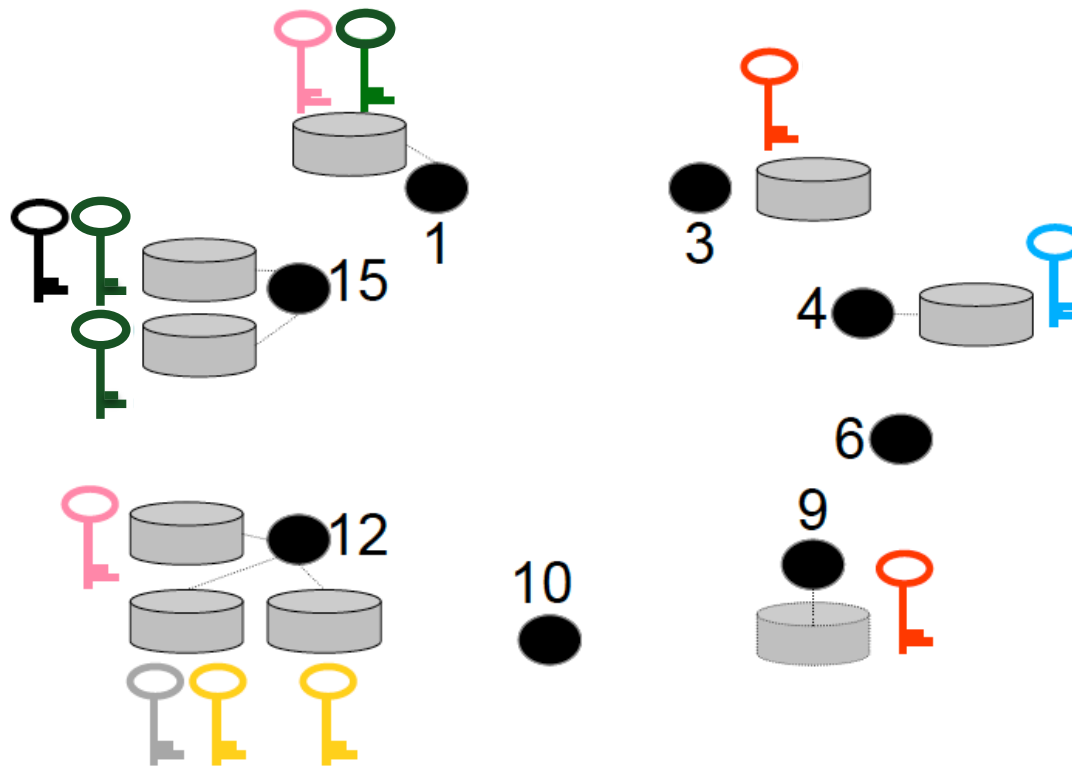
Structured P2P network

- Peers form a logical address space $0 \dots 2^k - 1$
 - Some positions may be empty
 - The peer position is obtained with the help of a **hash function**
 - e.g., $H(\text{peer IP address}) = n$, $0 \leq n \leq 2^k - 1$
 - This also leads to the name: **distributed hash table, DHT**
- The global data catalog is created and **distributed across the peers**, using the same hash function (see next)

Catalog construction (indexing) in structured P2P networks

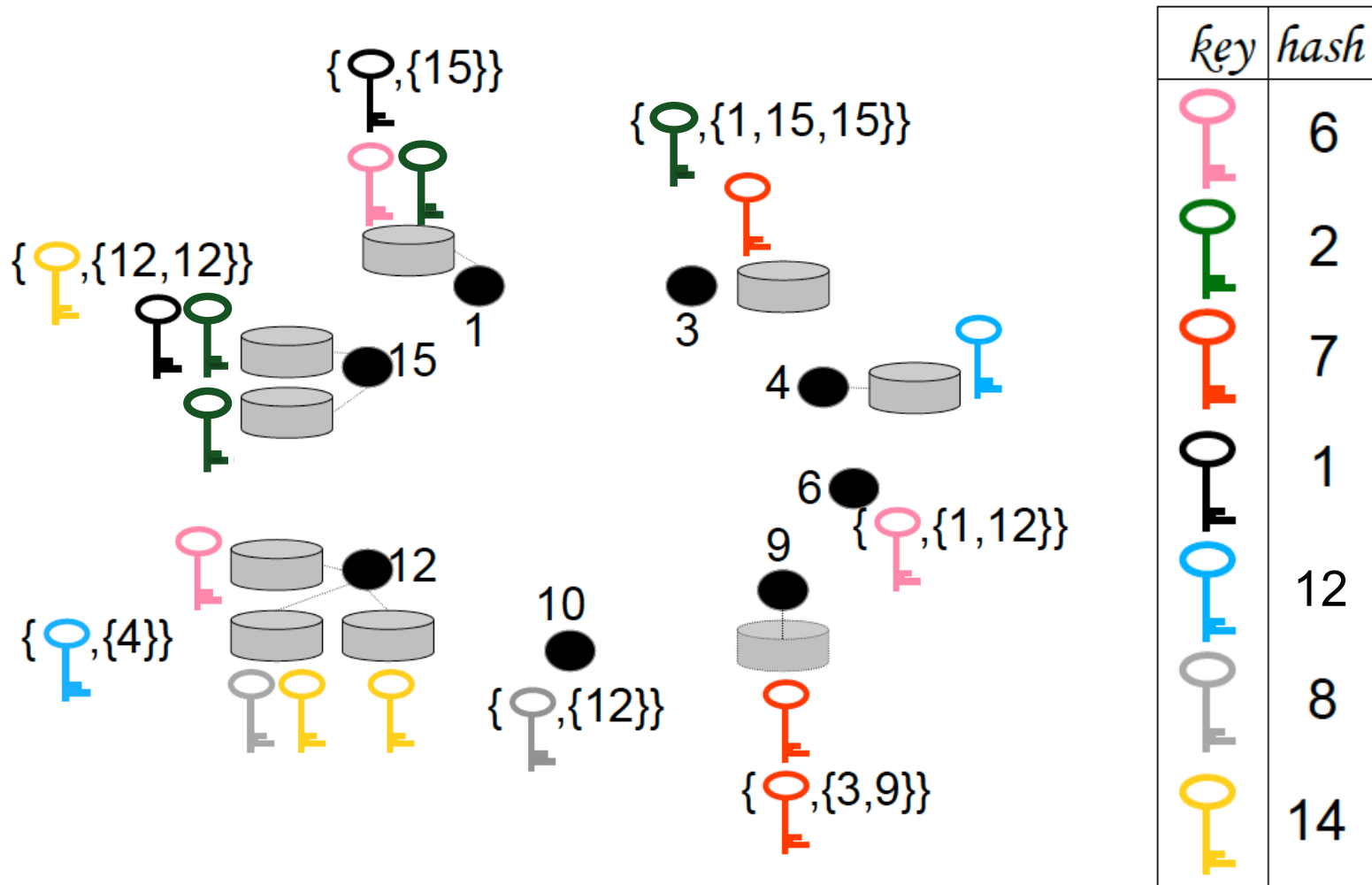
- The **catalog** is built as a set of key-value pairs
 - **Key**: expected to occur in search queries, e.g. «GoT », « Mr Robot »
 - **Value**: the address of content in the network matching the key, e.g. « peer5/Users/a/movies/GoT »
- A **hash function** is used to map every *key* into the address space; this distributes (*key*, value) pairs
 - $H(key)=n \rightarrow$ the (*key*, value) pair is sent to peer n
 - If n is empty, the next peer in logical order is chosen

Catalog construction (indexing) in structured P2P networks



<i>key</i>	<i>hash</i>
	6
	2
	7
	1
	12
	8
	14

Catalog construction (indexing) in structured P2P networks



Searching in structured P2P networks

Locate all items characterized by  ?

Hash()=6

Peer 6 knows all the locations

Locate all items characterized by  ?

Hash()=14

Peer 15 knows all the locations

How do we *physically* find peers 6 and 15?

Connections between peers in structured P2P networks

A peer's connections are dictated by the network organization and the logical address of each peer in the space $0 \dots 2^k - 1$

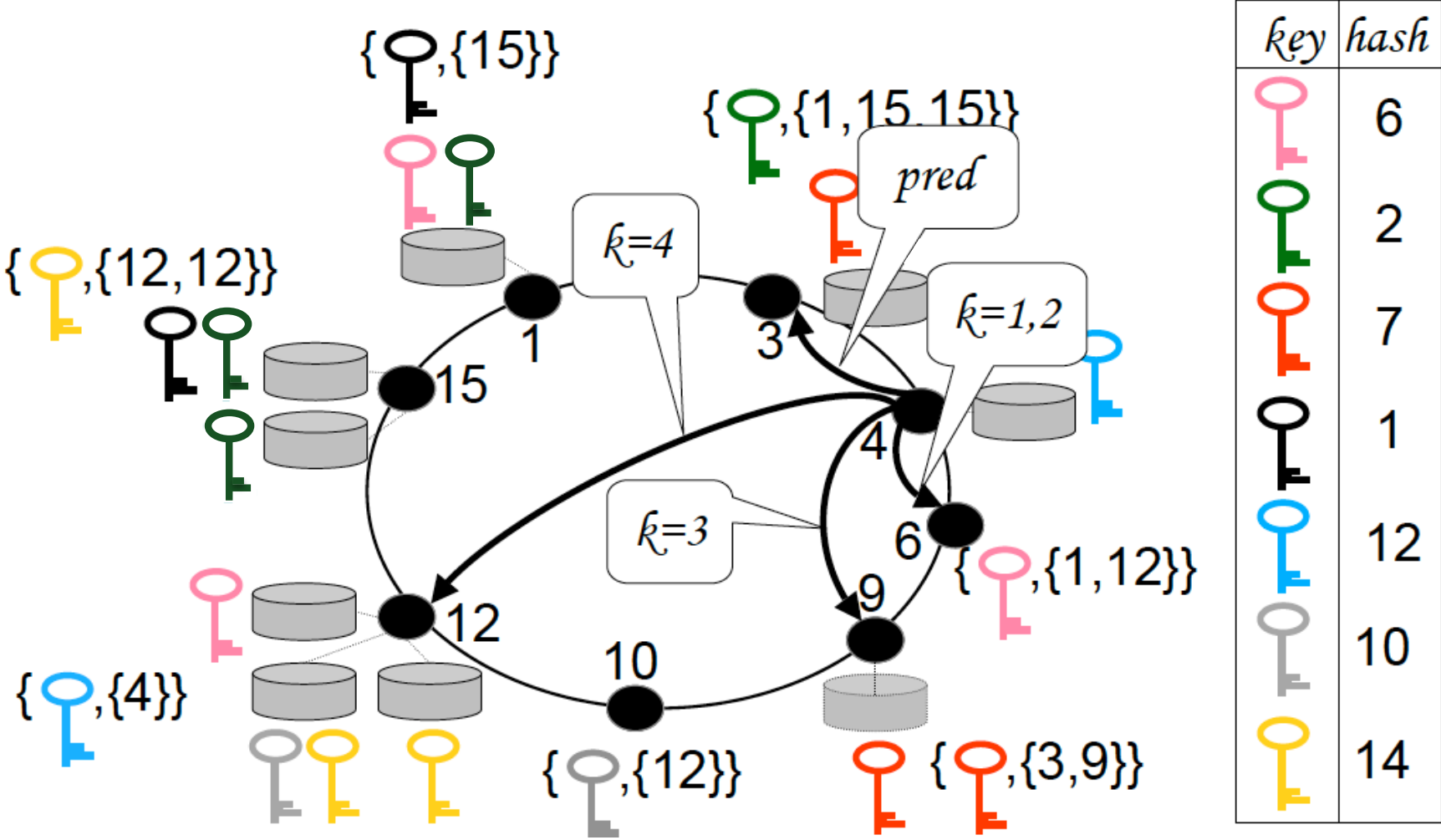
Example: Chord (MIT, most popular)

Each peer n is connected to

- $n+1, n+2, \dots, n+2^{k-1}$, or to the first peer *following* that position in the address space;
- The *predecessor of n*

The connections are called *fingers*

Connections between peers in Chord



Searching in structured P2P networks

Locate all items characterized by ?

- $\text{Hash}(\text{key})=6$
- Peer 6 knows all the locations

How does peer 1 find peer 6?

- $6-1=5$; $2 \leq \log_2(5) \leq 3$, thus 6 is between $1 + 2^2$ and $1 + 2^3$
- Redirect the question to the 2nd finger of 1.

How does peer 10 find peer 3?

- $(3 -_{\text{modulo } 16} 10)=9$; $3 \leq \log_2(9) \leq 4$, thus 3 is after $10 + 2^3$
- Redirect the question to the 3rd finger of 10.

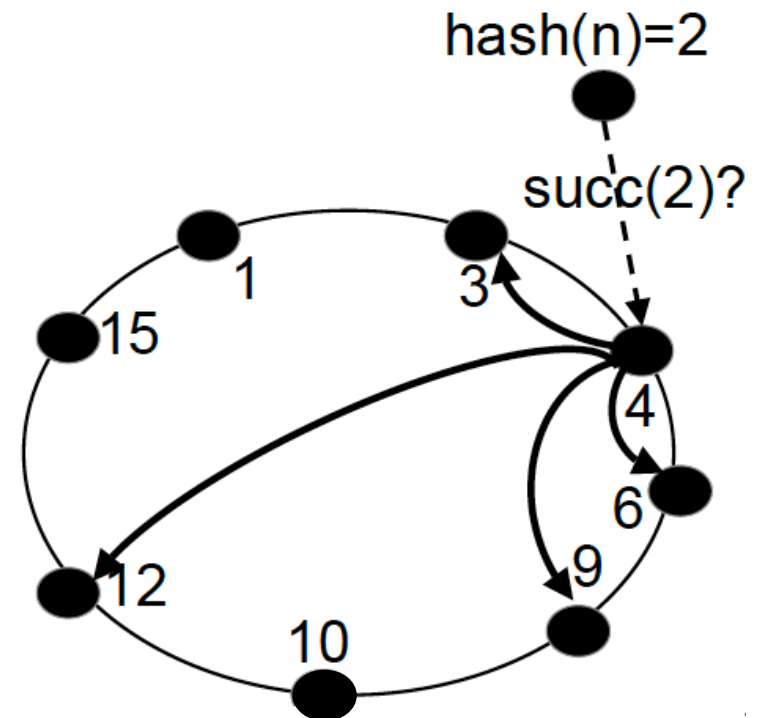
Quick traversals of the ring ($\log_2(N)$ hops)

Peers joining in Chord

To join, a peer n must know (any) peer n' already in the network

Procedure $n.join(n')$:

```
s = n'.findSuccessor(n);  
buildFingers(s);  
successor=s;
```

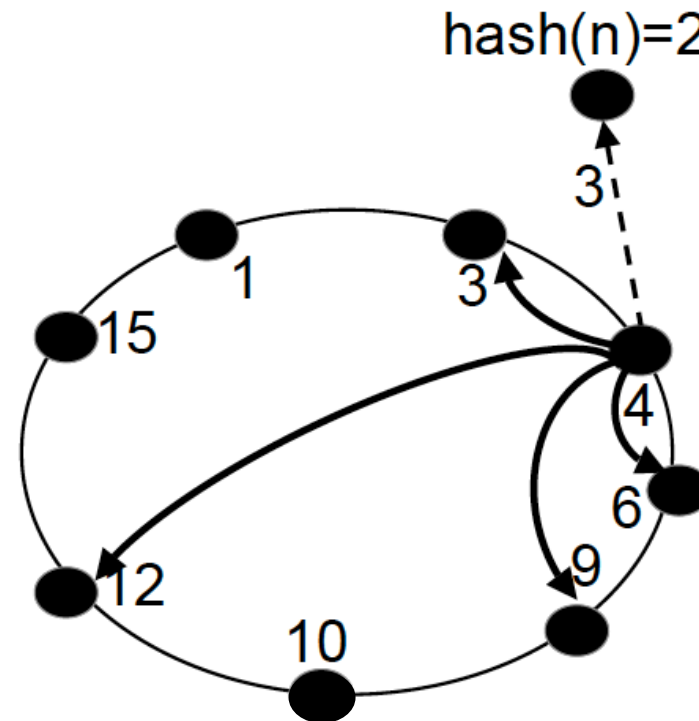


Peers joining in Chord

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Peers joining in Chord

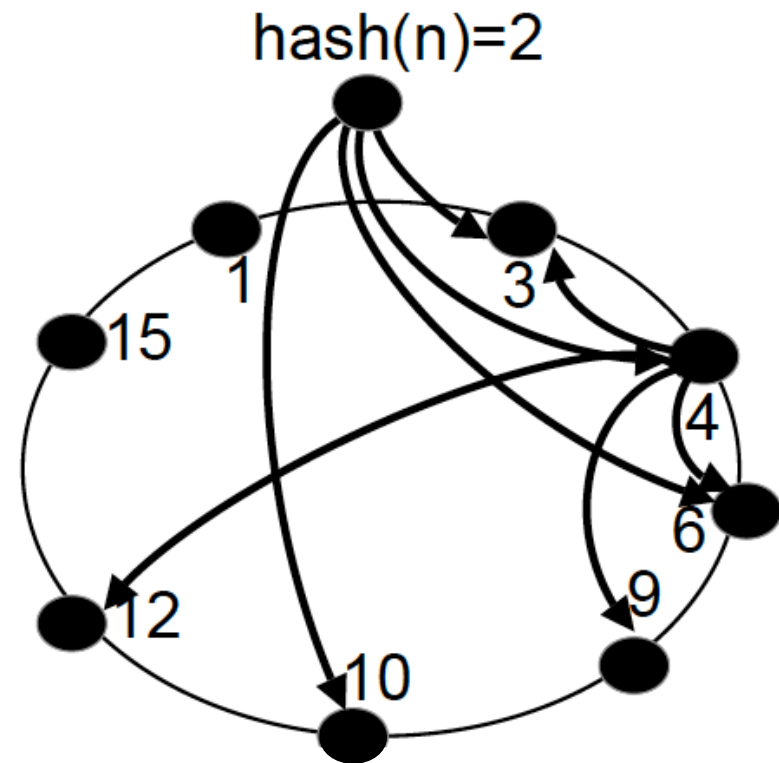
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```

If 3 had some key-value pairs for the key 2, 3 gives them over to 2

The network is not *stabilized* yet...



Network stabilization in Chord

Each peer periodically runs stabilize()

n.stabilize():

$x = n.\text{succ}().\text{pred}()$

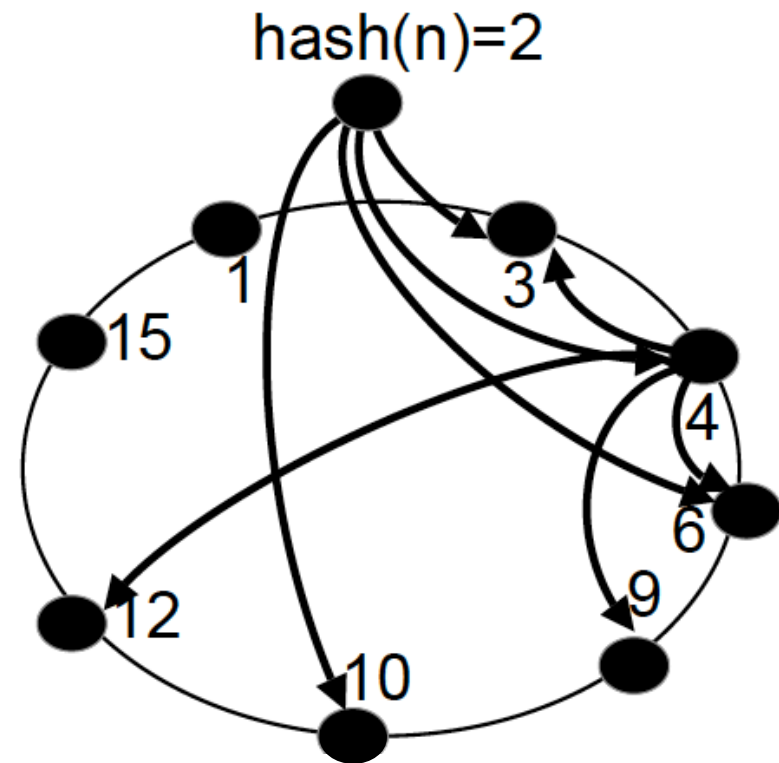
if $(n < x < \text{succ})$ then $\text{succ} = x$;

$\text{succ}.\text{notify}(n)$

n.notify(p):

if $(\text{pred} < p < n)$

then $\text{pred} = p$



Network stabilization in Chord

First stabilize() of 2: 3 learns its new predecessor

n.stabilize():

$x = n.succ().pred()$

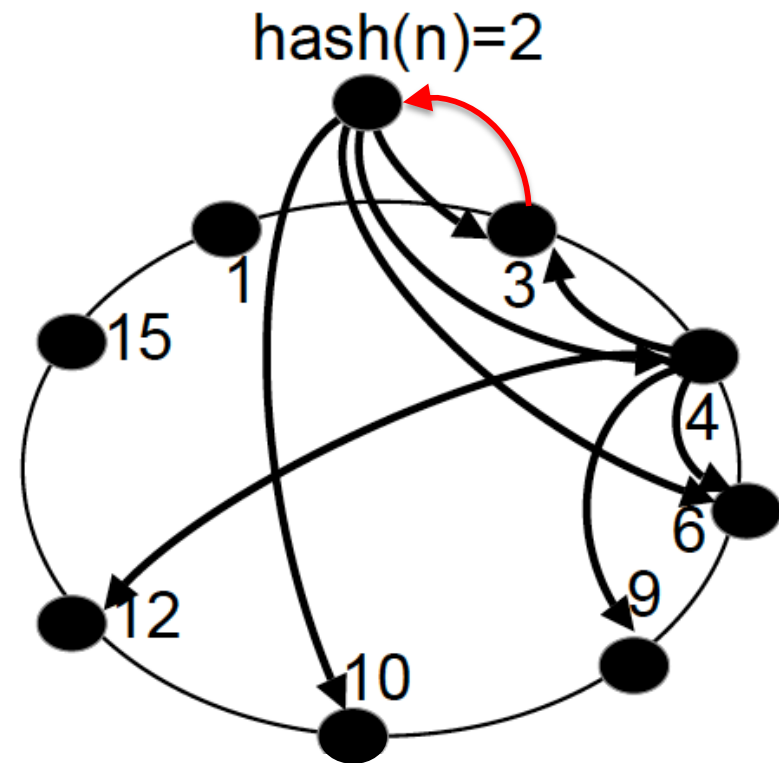
if $(n < x < succ)$ then $succ = x$;

$succ.notify(n)$

n.notify(p):

if $(pred < p < n)$

then $pred = p$



Network stabilization in Chord

First stabilize() of 1: 1 and 2 connect

n.stabilize():

$x = n.\text{succ}().\text{pred}()$

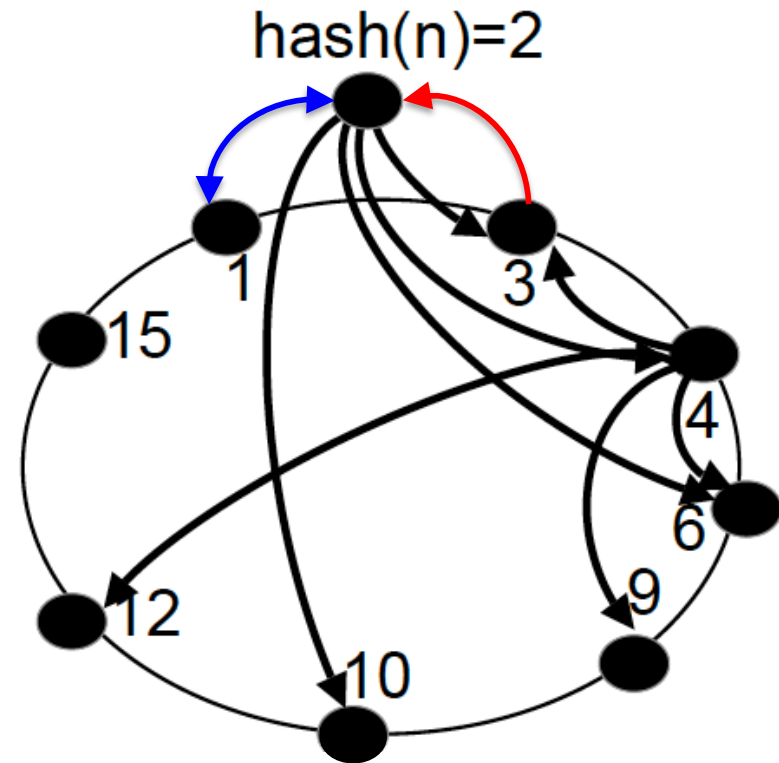
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then $\text{pred} = p$



Peer leaving the network

- The peer leaves (with some advance notice, « in good order »)
- Network adaptation to peer leave:
 - (key, value) pairs: those of the leaving peer are moved to its successor
 - Routing: P notifies successor and predecessor, which reconnect "over P"

Peer failure

- Without warning
- In the absence of replication, the (key, value) pairs held on P are **lost**
 - Peers may also re-publish periodically

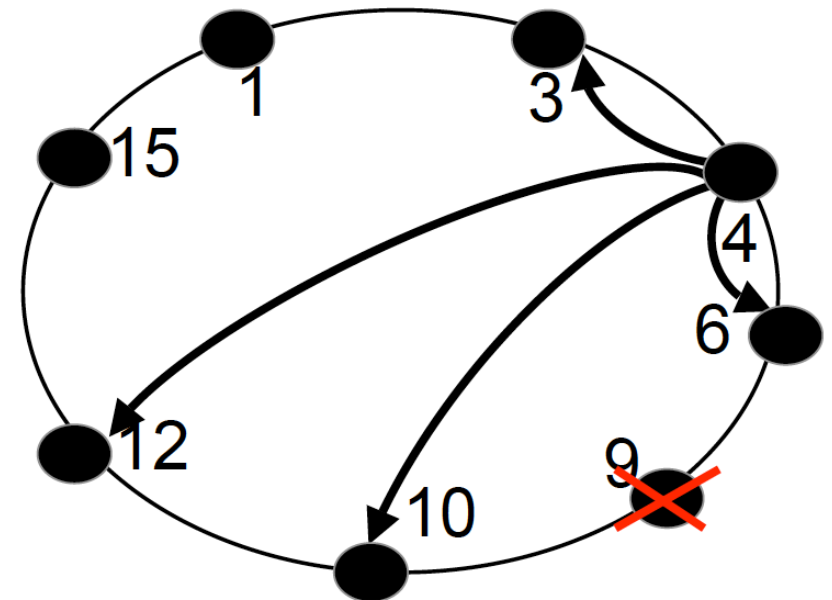
Example Running `stab()`, 6 notices 9 is down

6 replaces 9 with its next finger 10 →

all nodes have correct successors,
but fingers are wrong

Routing still works, even if a
little slowed down

Fingers must be recomputed



Peer failure

Chord uses successors to adjust to any change

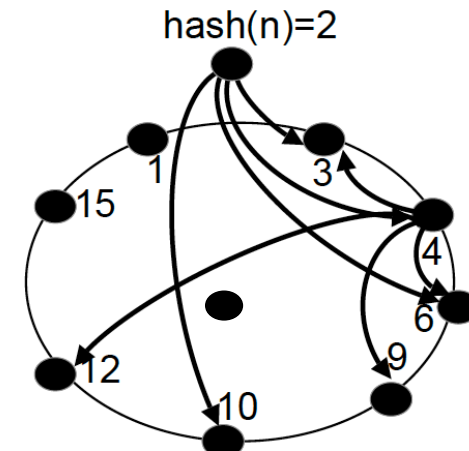
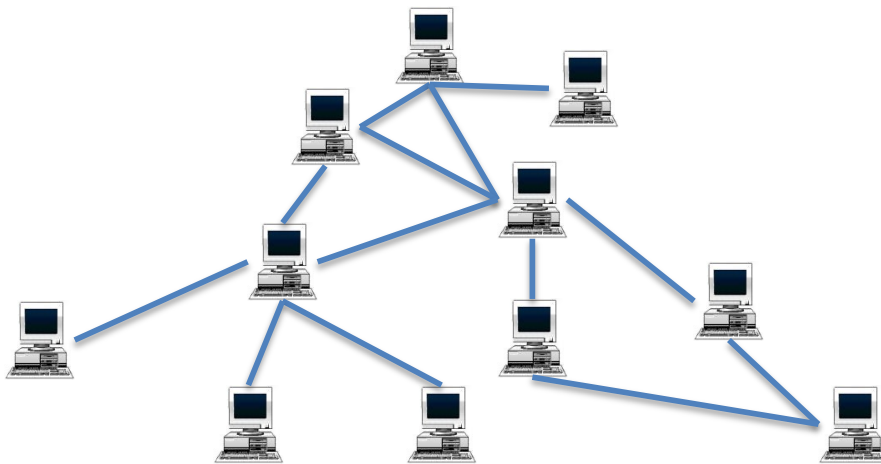
- Adjustment may « slowly propagate » along the ring, since it is relatively rare

To prevent erroneous routing due to successor failure, each peer maintains a list of its r direct successors ($2 \log_2 N$)

- When the first one fails, the next one is used...
- All r successors must fail simultaneously in order to disrupt search

Gossip in P2P architectures

- Constant, « background » communication between peers
- Structured or unstructured networks
- Disseminates information about peer network, peer data

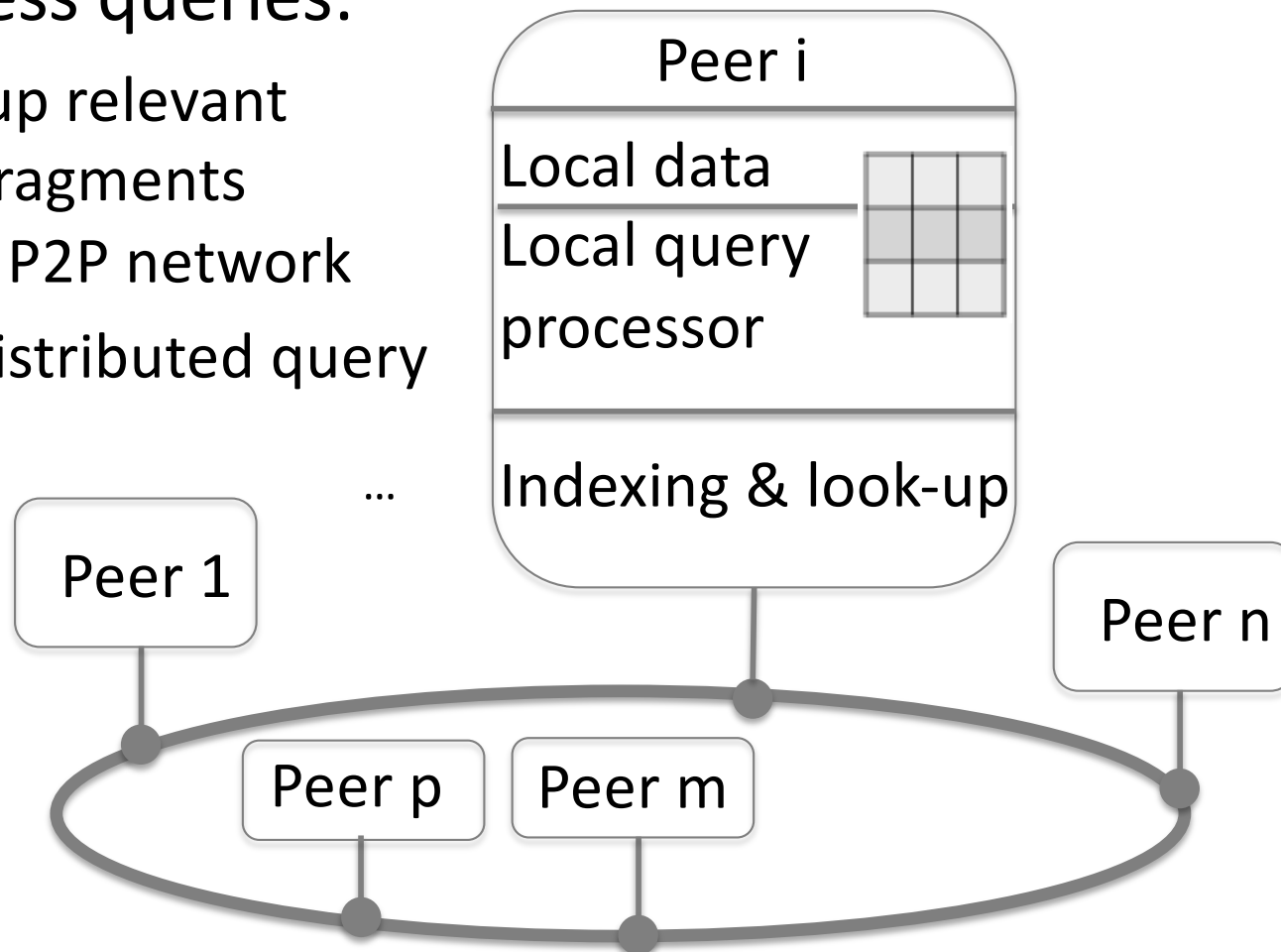


Peer-to-peer networks: wrap-up

- **Data model:**
 - Catalog and search at a simple key level
- **Query language:** keys
- **Heterogeneity:** not the main issue
- **Control:**
 - peers are autonomous in storing and publishing
 - query processing through symmetric algorithm (except for superpeers)

Peer-to-peer data management

- Extract key-value pairs from the data & index them
- To process queries:
 - Look up relevant data fragments in the P2P network
 - Run distributed query plan



Example: storing relational data in P2P data management platform

- Each peer stores a horizontal slice of a table
- Catalog **at the granularity of the table**:
 - Keys: table names, e.g. **Singer**, **Song**
 - Value: fragment description, e.g.,
`peer1:postgres:sch1/Singer&u=u1&p=p1,`
 - Query: `select Singer.birthday
from Singer, Song
where Song.title= « Come Away » and
Singer.sID=Song.singer`
 - What can happen?
- Try other granularities

Modern P2P data management system: Cassandra



- Partitioned row store, fully symmetric structured P2P architecture
- Based on the Dynamo K-V system [CHG+07]
- Some nesting; indexes. Queries: select, project.

Table **songs**:

id	song_order	album	artist	song_id	title
62e36092...	4	No One Rides for Free	Fu Manchu	7db1a490...	Ojo Rojo
62e36092...	3	Roll Away	Back Door Slam	2b09185b...	Outside Woman Blues
62e36092...	2	We Must Obey	Fu Manchu	8a172618...	Moving in Stereo
62e36092...	1	Tree Hombres	ZZ Top	a3e64f8f...	La Grange

ALTER TABLE songs ADD tags set<text>;

UPDATE songs SET tags = tags + {'2007'} WHERE id = 8a172618...;

UPDATE songs SET tags = tags + {'covers'} WHERE id = 8a172618...;

UPDATE songs SET tags = tags + {'1973'} WHERE id = a3e64f8f-...;

SELECT id, tags from songs;

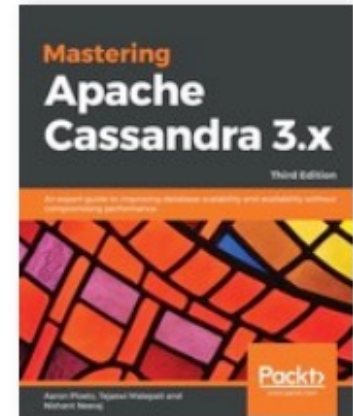
id	tags
7db1a490-5878-11e2-bcfd-0800200c9a66	{rock}
a3e64f8f-bd44-4f28-b8d9-6938726e34d4	{blues, 1973}
8a172618-b121-4136-bb10-f665cfc469eb	{2007, covers}

Modern P2P data management system: Cassandra



Large Cassandra deployments:

- Apple: over 75,000 nodes storing over 10 PB of data
- Netflix: 2,500 nodes, 420 TB, over 1 trillion requests per day



CAP trade-off: timeout for deciding when a node is dead

« During gossip exchanges, every node maintains a **sliding window of inter-arrival times of gossip messages from other nodes in the cluster**. Configuring the [phi_convict_threshold](#) property adjusts the sensitivity of the failure detector. Lower values increase the likelihood that an unresponsive node will be marked as down, while higher values decrease the likelihood that transient failures causing node failure.

Use the default value for most situations, but **increase it to 10 or 12 for Amazon EC2** (due to frequently encountered network congestion) to help prevent false failures.

Values **higher than 12 and lower than 5** are not recommended. »