Architectural styles for software systems

Peer to Peer

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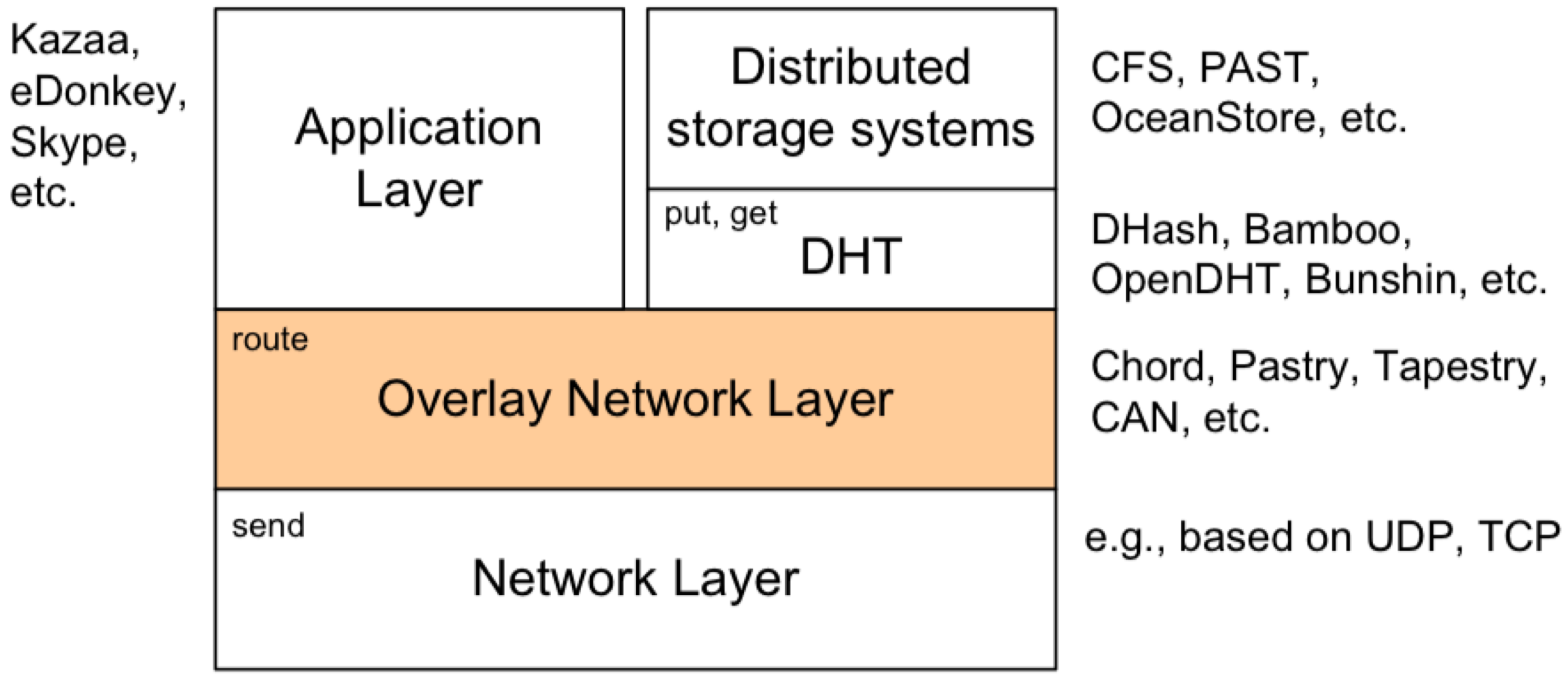
Agenda

- P2P: overview
- Basic types of P2P systems
- Case study: Skype
- Case study: Bitcoin

Peer to peer computing

- a class of applications that takes advantage of resources— storage, cycles, content, humans — available at the edges of the Internet
- Because accessing these decentralized resources means operating in an environment of unstable connectivity and unpredictable IP addresses, peer-to-peer nodes must operate outside the DNS system and have autonomy from central servers

Layers in P2P

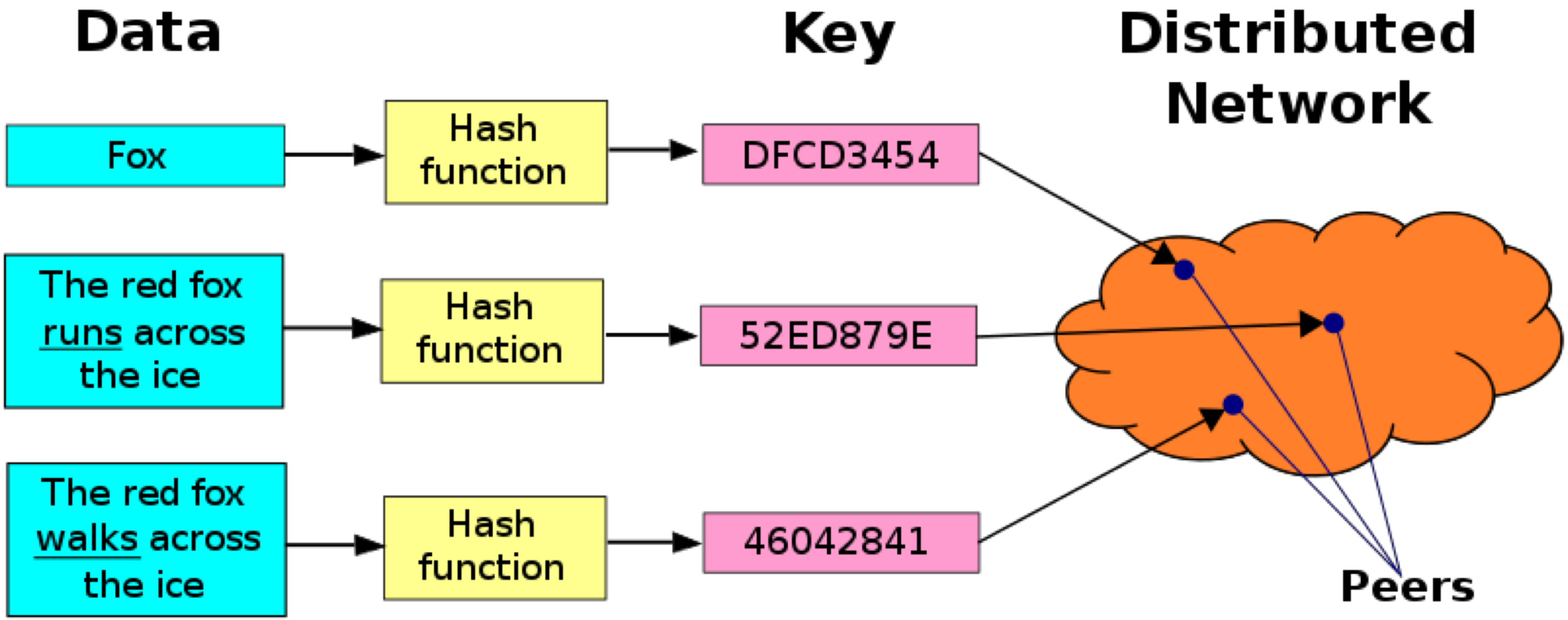


The overlay network layer is responsible for implementing an efficient routing algorithm: the nodes in the system are structured in order to decrease the search steps necessary to find the target identifier.

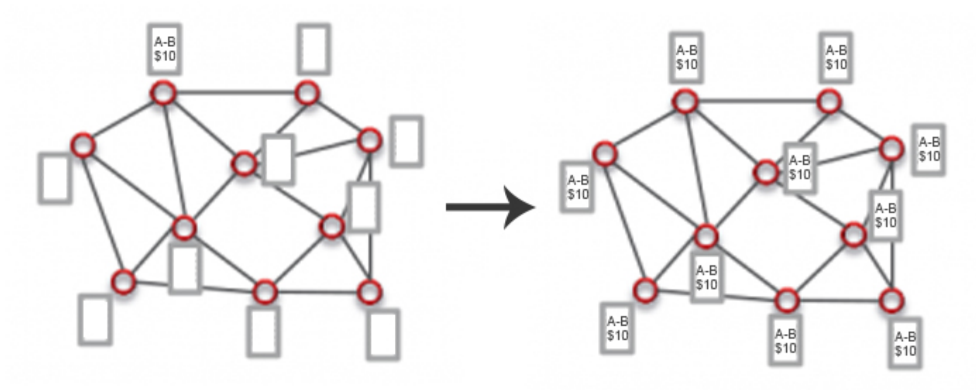
Each node maintains a local routing table, which holds the identifiers of other nodes in the system

Distributed hash tables

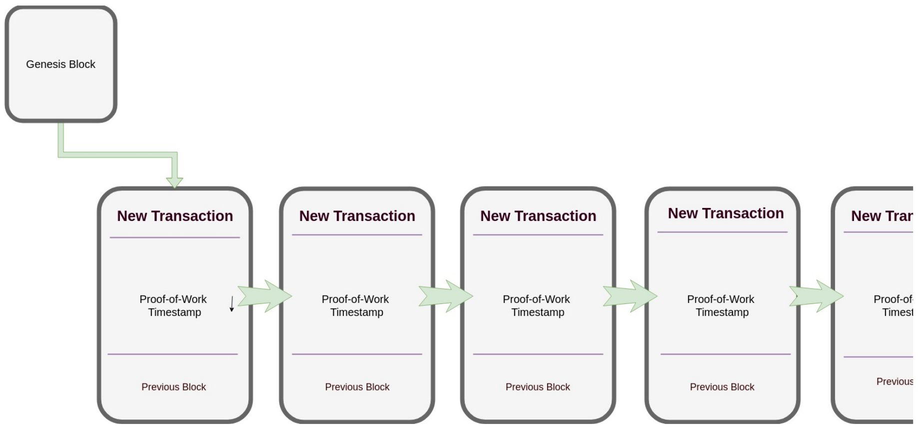
A distributed hash table (DHT) provides a lookup service similar to a hash table: (key, value) pairs are stored in a DHT, and any participating node can efficiently retrieve the value associated with a given key



Distributed ledgers and blockchains

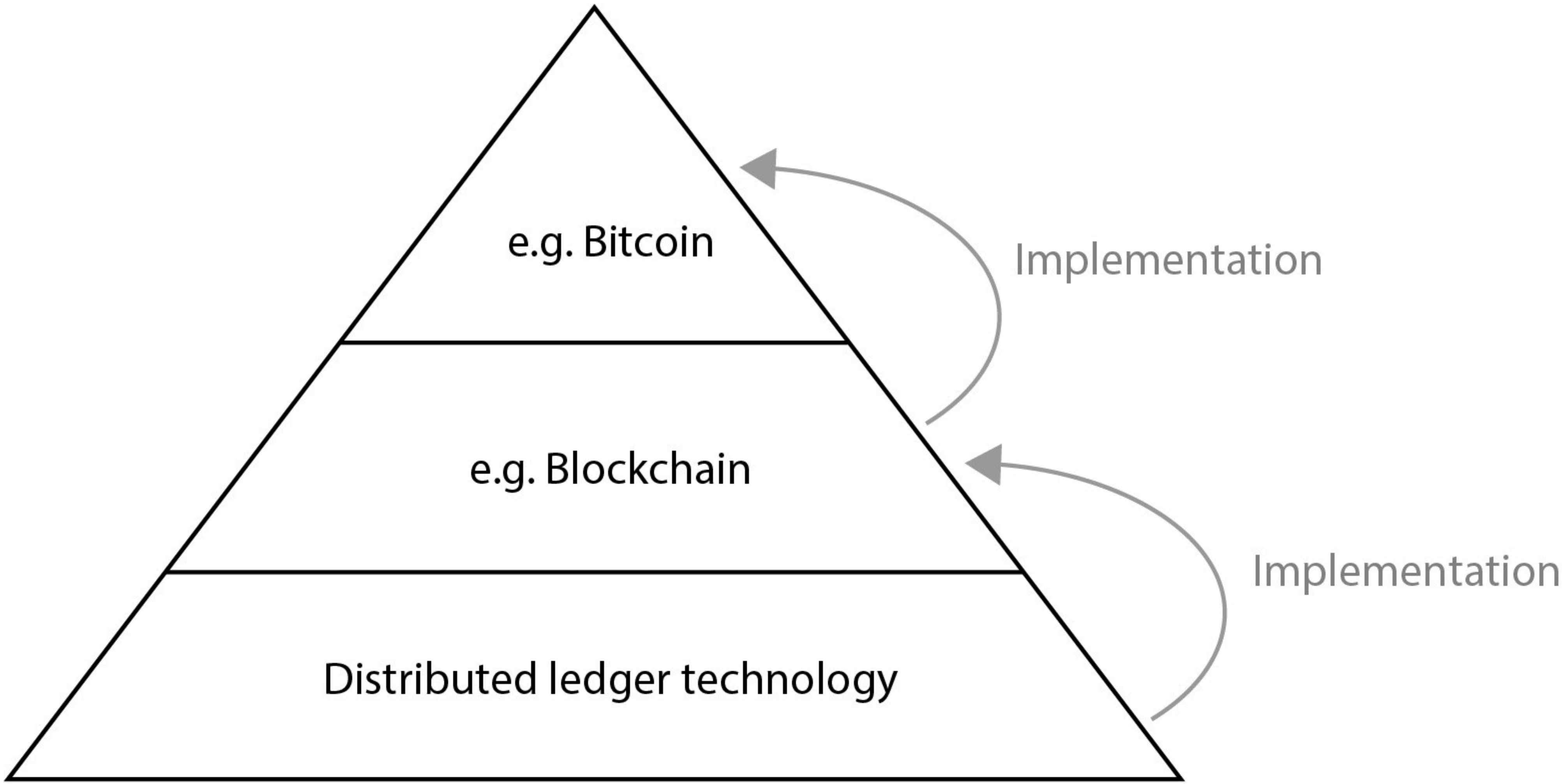


Distributed ledger



Blockchain

Distributed ledgers vs blockchains



P2P: Overview

- A P2P system is a distributed collection of peer nodes
- Each node is able to provide services, as well as to make requests, to other nodes
  - Each node acts as both a server and a client
- The goal of this style:
  - To share resources and services (data, CPU, disk,…)

Peer-to-peer systems

- File sharing systems based on BitTorrent
- Messaging systems such as Jabber
- Blockchains – Bitcoin and Ethereum
- Databases – Freenet is a decentralized database
- Phone systems – Viber or Skype
- Computation systems - SETI@home

P2P: requirements and drivers

- Typical functional characteristics of P2P systems:
  - File sharing system
  - File storage system
  - Distributed file system
  - Redundant storage
  - Distributed computation
- Typical non-functional requirements:
  - Availability
  - Reliability
  - Performance
  - Scalability
  - Anonymity

Peer: CRC

Class Peer	**Collaborators**
Responsibilities •Component •Handles User interaction •Asks other Peers for searching some data •Asks some Peers for obtaining some data	

P2P: Brief History

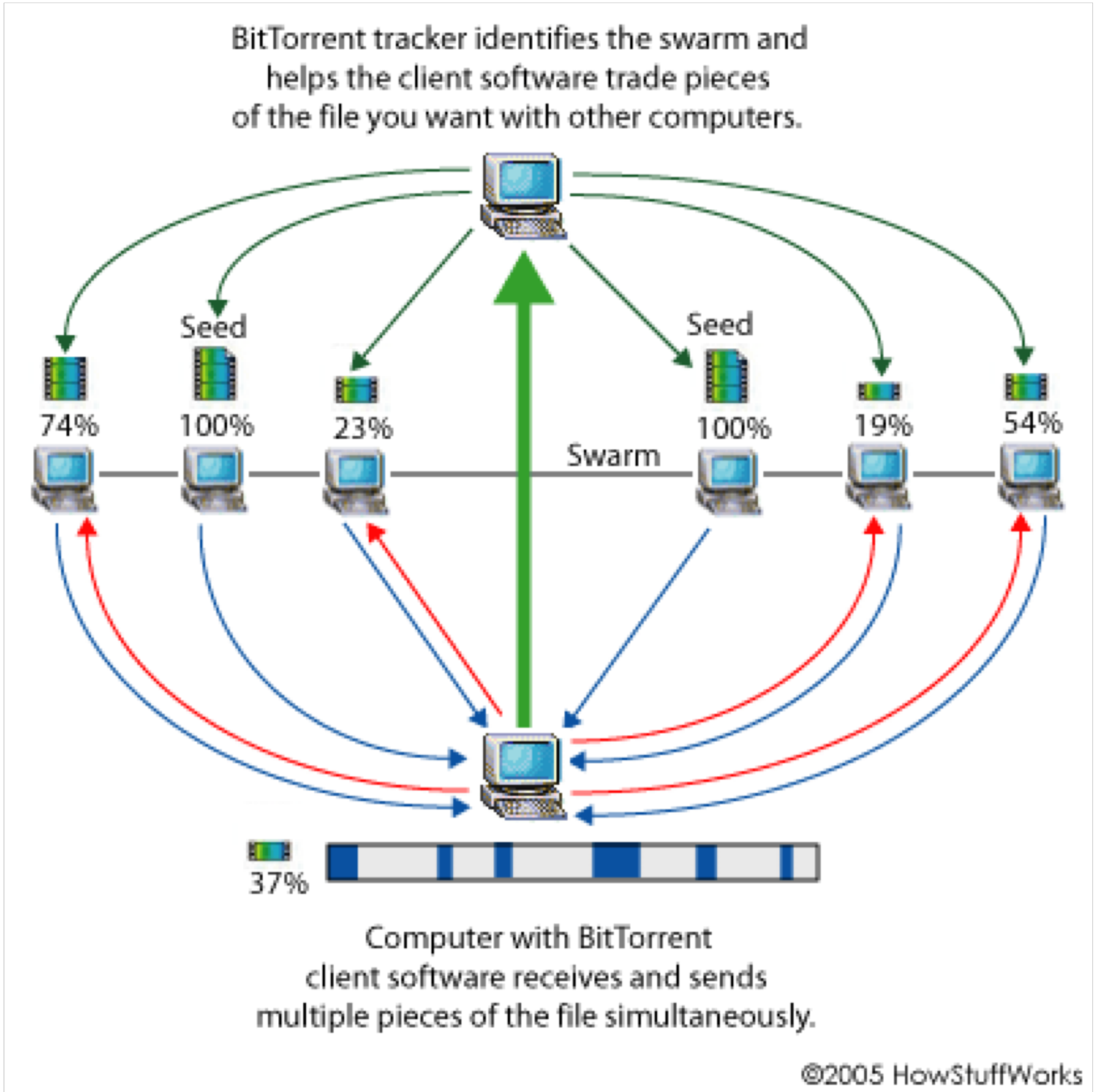
- Although they were proposed several years ago, they mainly evolved in the last 20 years
- File sharing systems showed the power of the concept (Napster, 1999; Gnutella, 2000)
- In 2000, the Napster client was downloaded in few days by 50 millions users
  - Traffic peak of 7 TB in a day
- Gnutella followed Napster's footprint
  - The first release was delivered in 2003
  - In June 2005, Gnutella's population was 1.81 million computers; in 2007, it was the most popular file sharing network with an estimated market share > 40%
  - Host servers are listed at gnutellahost.com

The phases of a P2P application

A P2P application is organized in three phases:

- **Boot**: a peer connects to the network and actually performs the connections (remark: P2P boot is rare)
- **Lookup**: a peer looks for a provider of a given service or information (generally providers are SuperPeers)
- **Resource sharing**: resources (requested and found) are delivered, usually in several segments

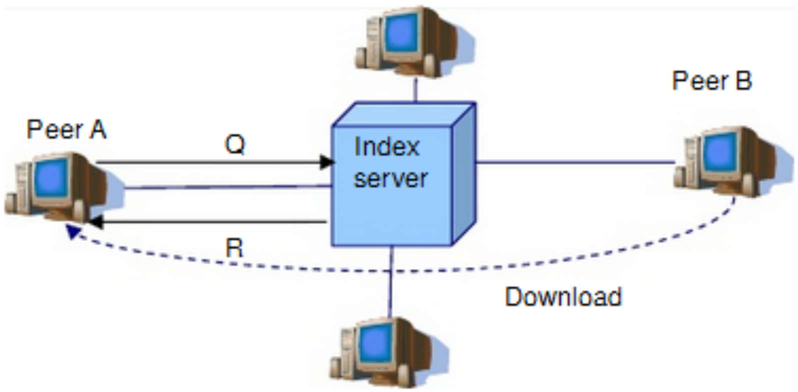
P2P resource sharing example: bitTorrent



P2P: Classification

- There are three types of P2P architecture, different with respect to the lookup phase:
  - **Centralized**
    - Centralized network architecture uses a centralized indexed server to maintain a database of all the content and users at any time
    - The database is updated whenever a peer logs on to the network
  - **Decentralized** (Pure P2P)
    - Each peer acts as an index server, searches and holds its own local resources, and as a router, relaying queries between peers
  - **Hybrid Architecture**
    - Deploys a hierarchical structure by establishing a backbone network of Super Nodes that take on the characteristics of a central index server

P2P: Centralized Index



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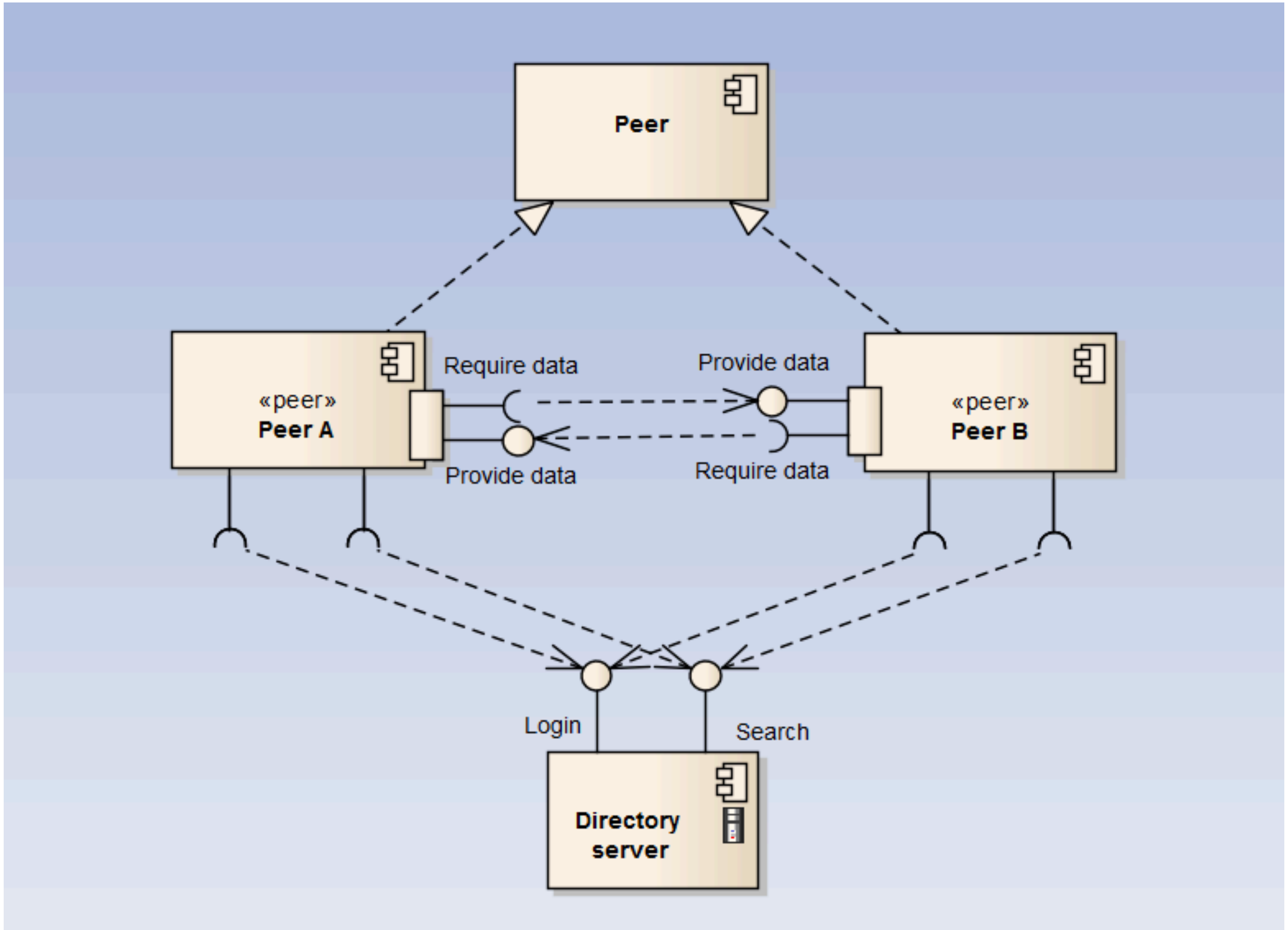
- There is a centralized index used to search the information
- When peer connects, it informs central server:
  - IP address
  - Content
- File transfer is decentralized, but locating content is highly centralized
- Example: *Napster*

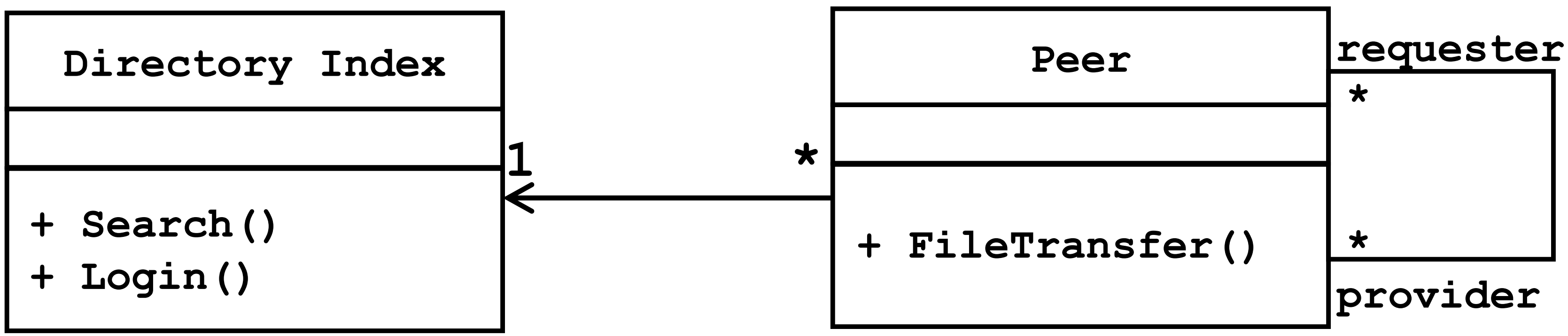
Centralized: Architecture

- Components:
  - **Peer**
    - An entity with capabilities similar to other entities in the system
    - Each node is both a server and a client
    - Autonomous: no administrative authority
    - Unreliable: nodes enter and leave the network "frequently"
  - **Index Server**
    - An entity with special capabilities:
      - Allow peer to join the system
      - Allow the research of content
    - Maintain a database of all the content and users at any time, which is updated whenever a peer logs on to the network
- Connectors:
  - **Network protocol**
    - Often specialized for P2P communication

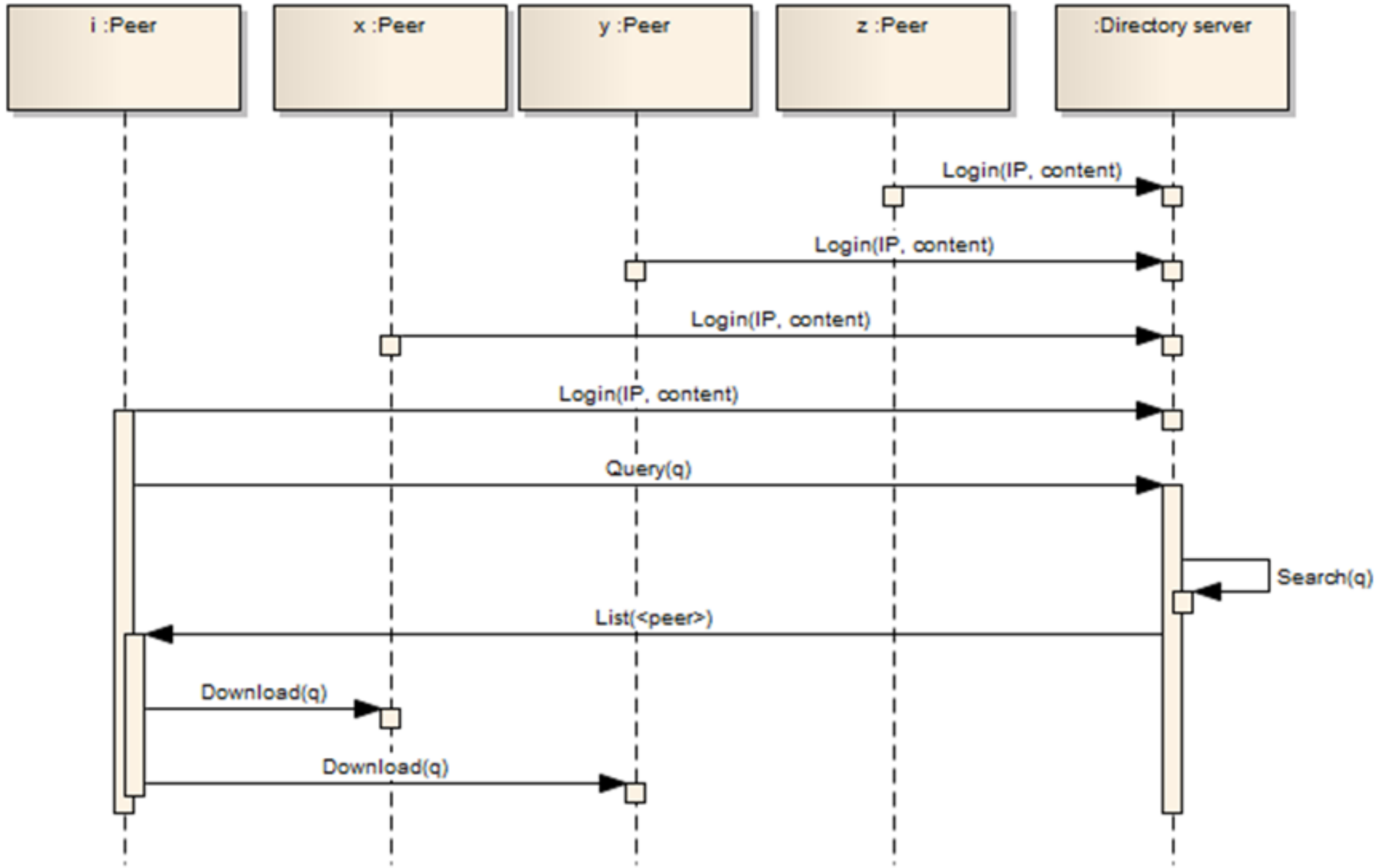
Centralized Index: Component Diagram



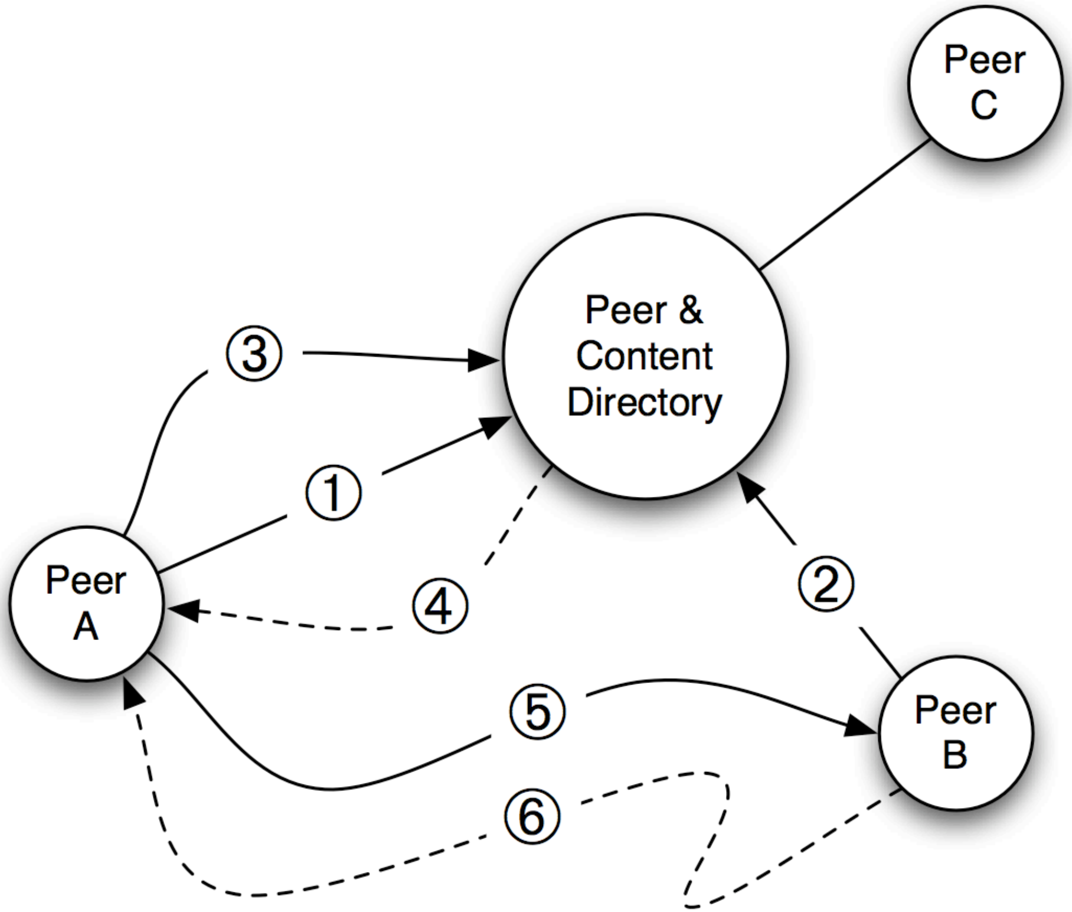
Centralized Index: Class Diagram

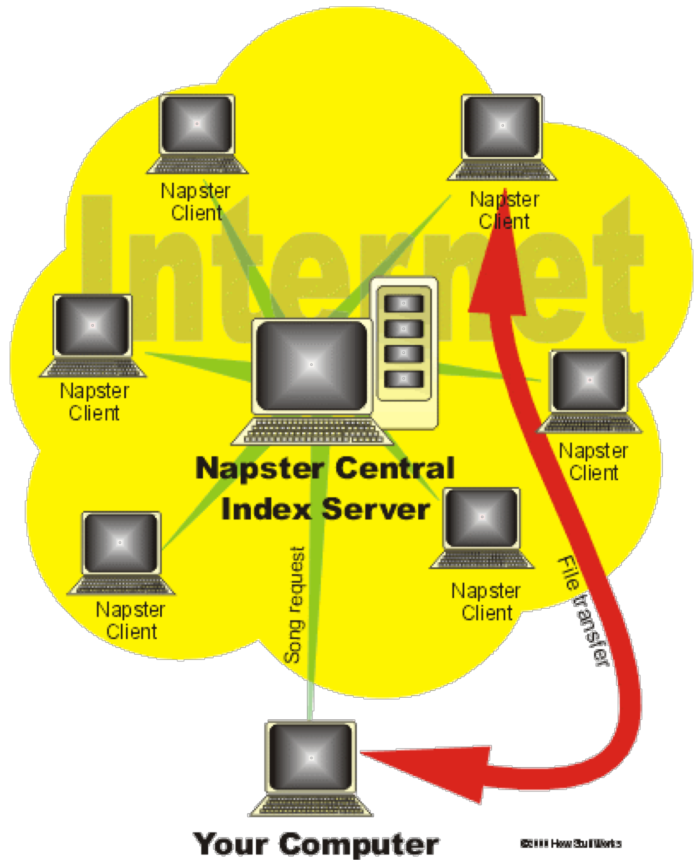


Centralized Index: Sequence Diagram



Centralized Index Example: Napster

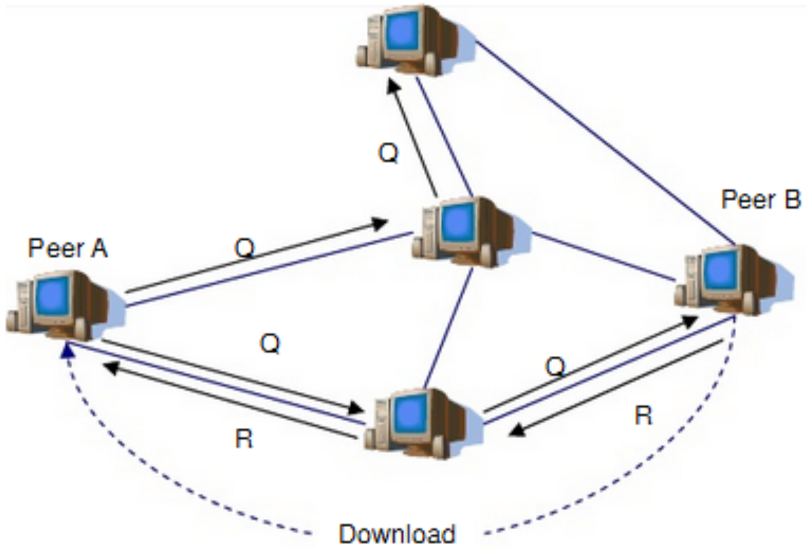




Centralized Index: Pro & Cons

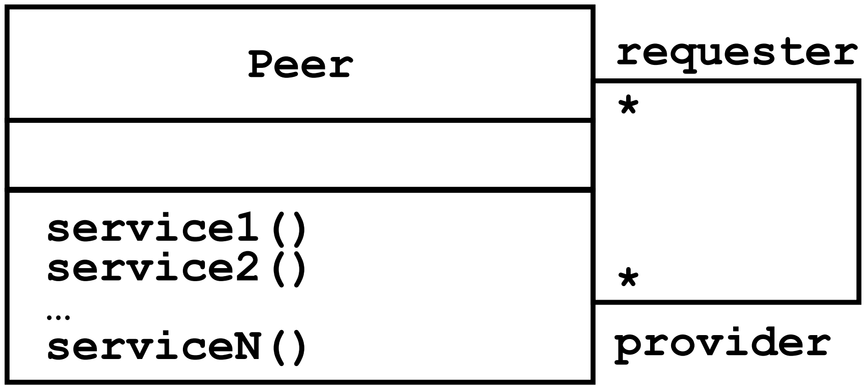
- Benefits:
  - Low per-node state
  - Limited bandwidth usage
  - High success rate
  - Fast search response time
  - Easy to implement and maintain
- Pitfalls:
  - Single point of failure
  - Vulnerable to censorship
  - Limited scale
  - Possibly unbalanced load
  - Database might be obsolete

P2P: Decentralized



- Decentralized P2P organizes the overlay network as a random graph
- Each node knows about a subset of nodes, its “neighbors”
  - Neighbors are chosen in different ways:
    - physically close nodes, nodes that joined at about the same time, etc.
- Example: *Gnutella, Bitcoin*

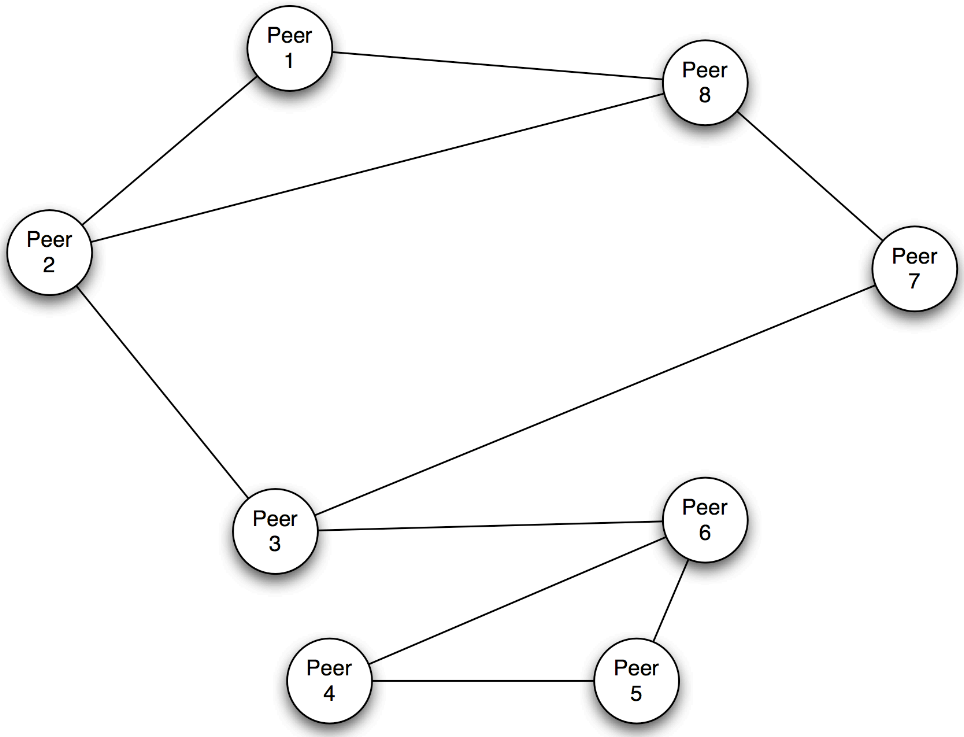
Decentralized : Class Diagram

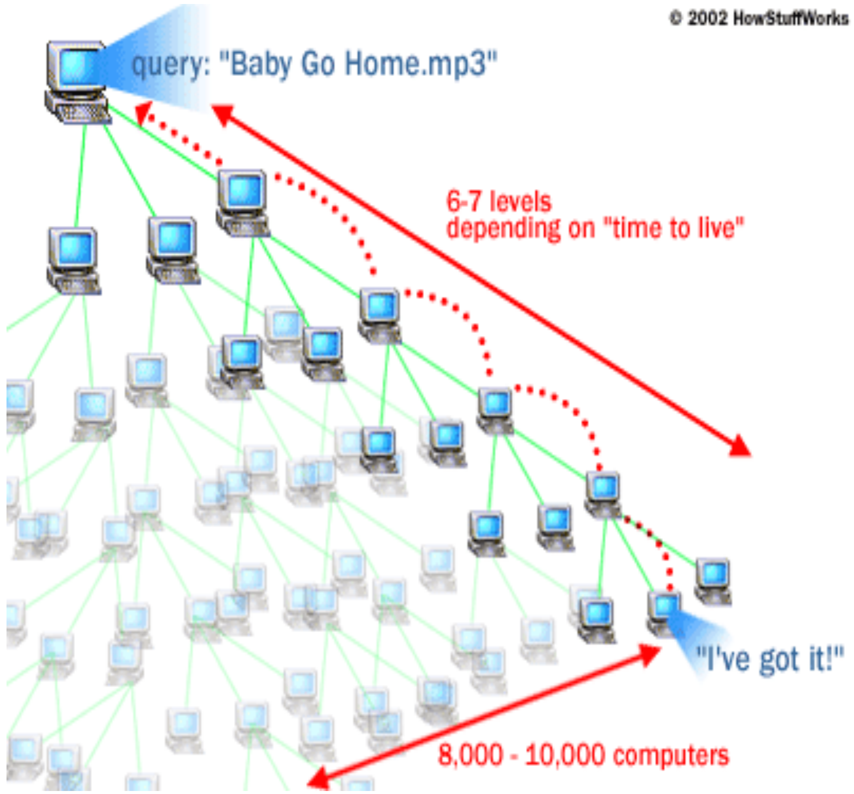


Decentralized: Architecture

- Components:
  - **Peer**
    - An entity with capabilities similar to other entities in the system
    - Each node is both a server and a client
    - Autonomous: no administrative authority
    - Unreliable: nodes enter and leave the network “frequently”
    - Local knowledge: nodes only know a small set of other nodes
- Connectors:
  - **Network protocol**
    - Often specialized for P2P communication

Decentralized Example: Gnutella





Decentralized: Component Diagram

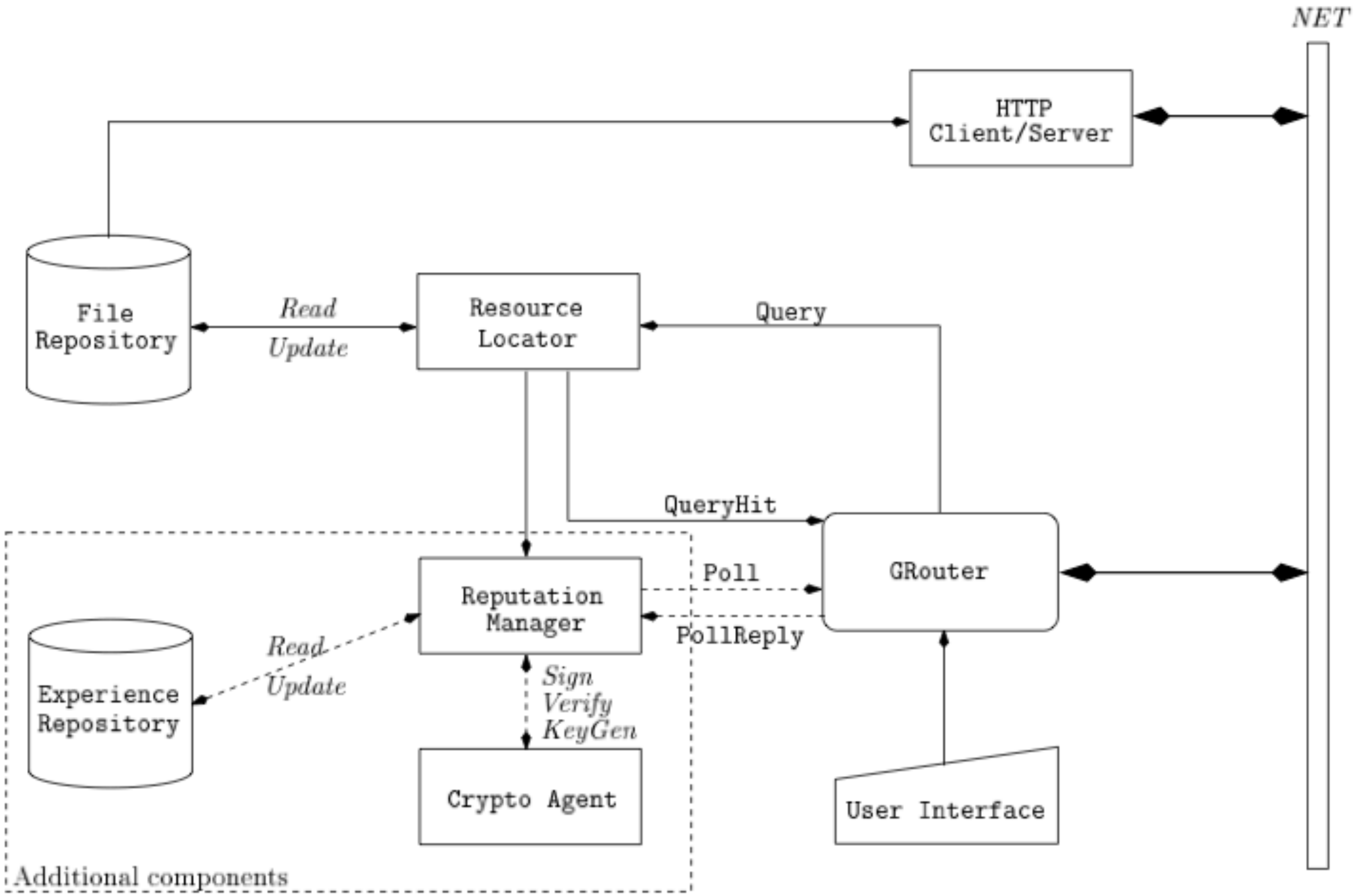


Fig. 2. Typical component-based structure of a Gnutella servent

Cornelli et al., Implementing a Reputation-Aware Gnutella Servent , Proc. Networking 2002

Decentralized: Sequence Diagram (1)

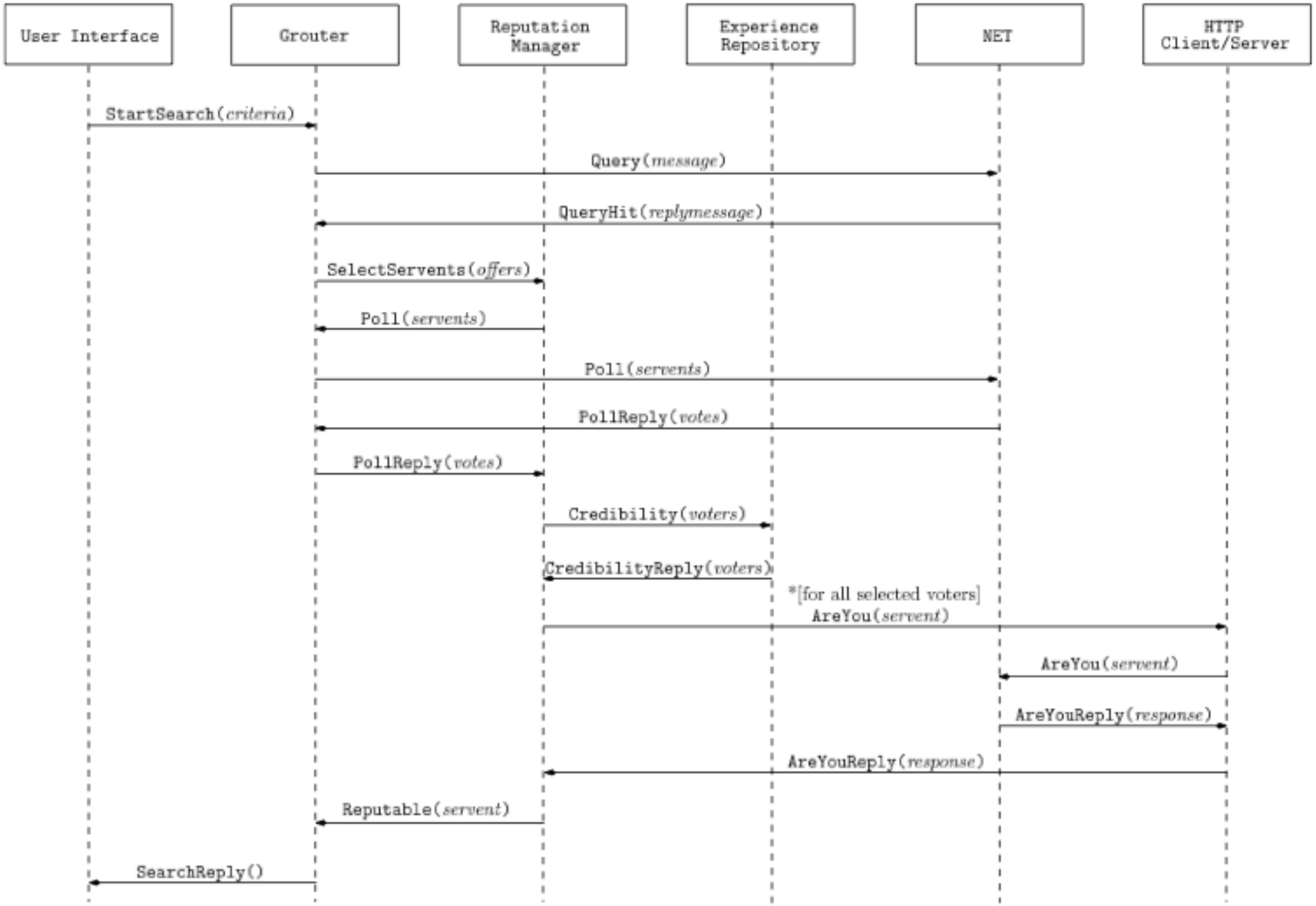


Fig. 3. UML Sequence diagram of a search session

Cornelli, Implementing a Reputation-Aware Gnutella Servent , 2002

Decentralized: Sequence Diagram (2)

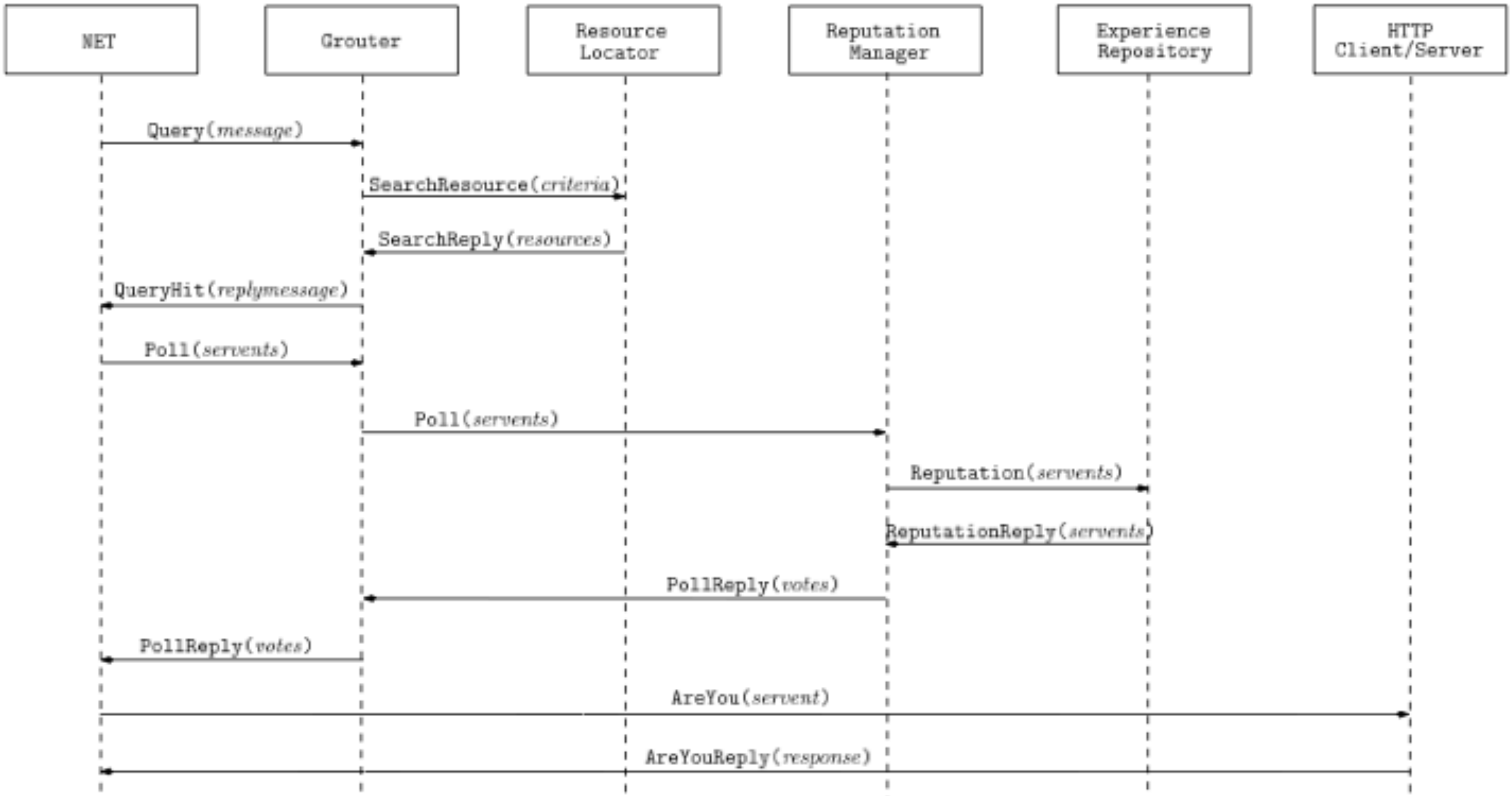
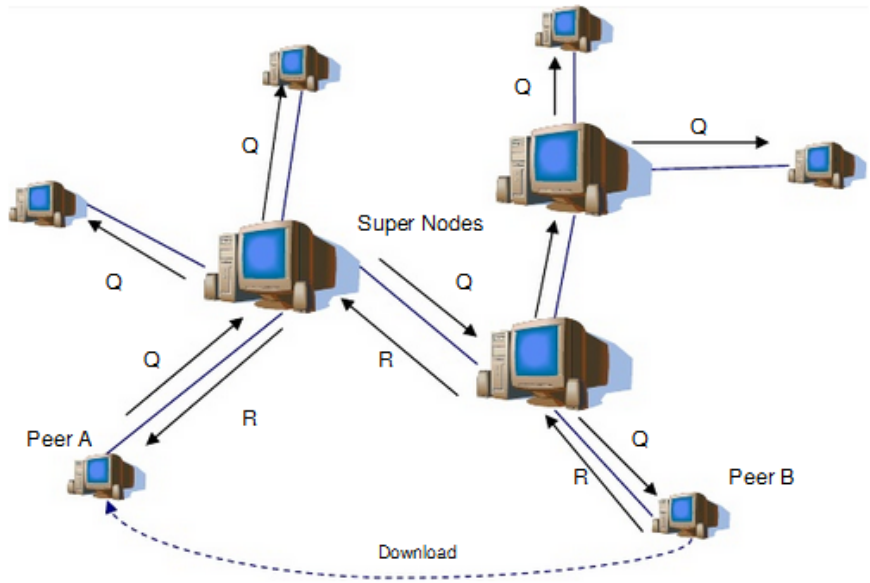


Fig. 4. UML Sequence diagram of a reply session

Decentralized: Pro & Cons

- Benefits:
  - Limited per-node state
  - Fault tolerant
- Pitfalls:
  - High bandwidth usage
  - Long time to locate item
  - No guarantee on success rate
  - Possibly unbalanced load

P2P: Hybrid Architecture



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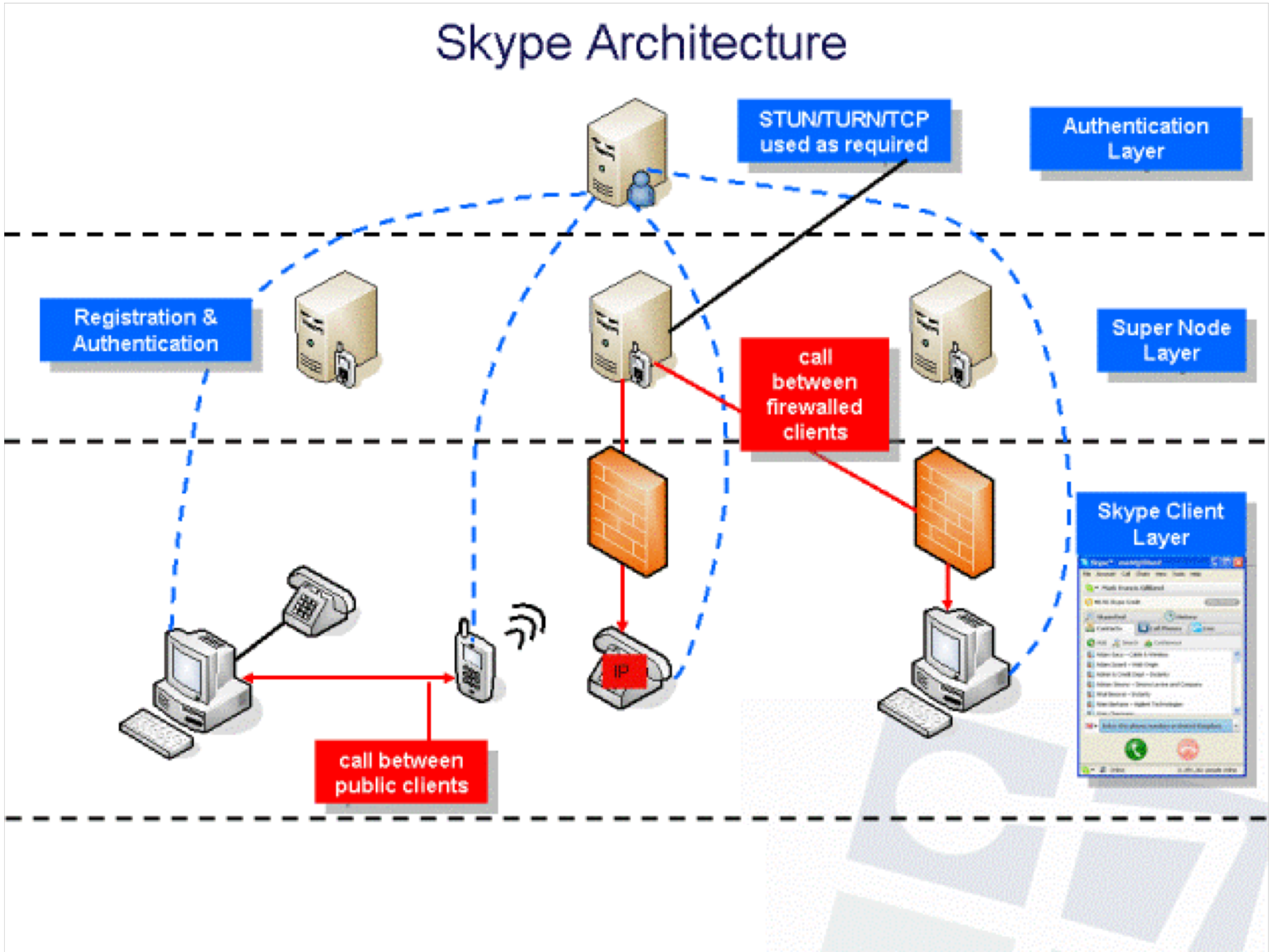
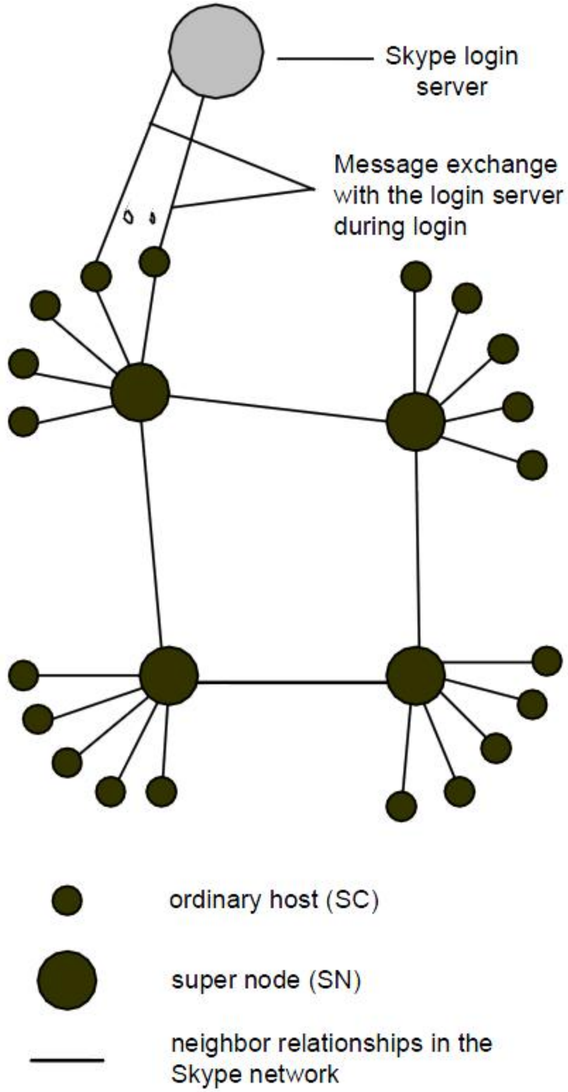
- Deploys a hierarchical structure by establishing a backbone network of Super Nodes that take on the characteristics of a central index server
- When a client logs on to the network, it makes a direct connection to a single **Super Peer**
- Example: *Skype*

Example: Skype

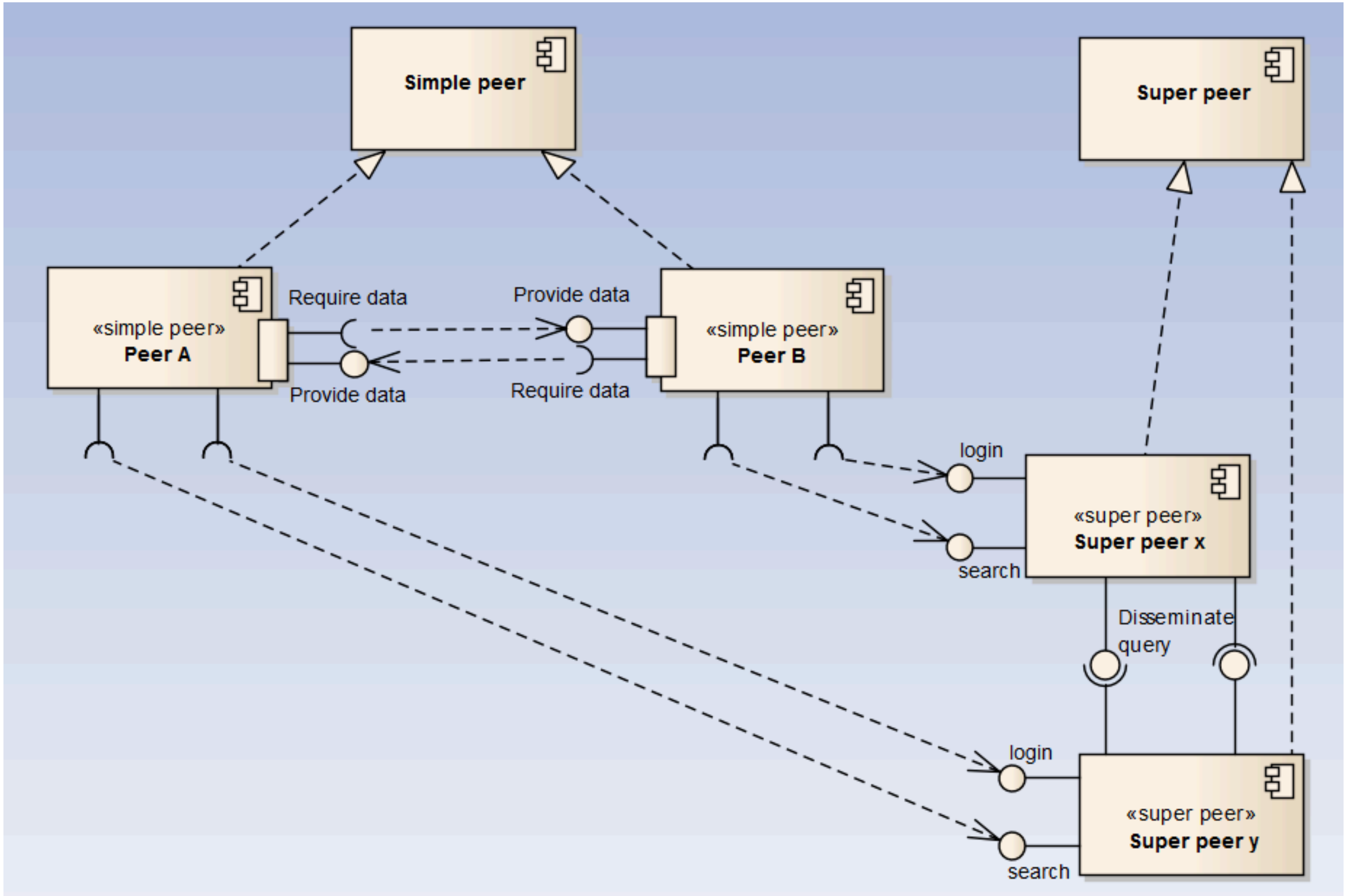




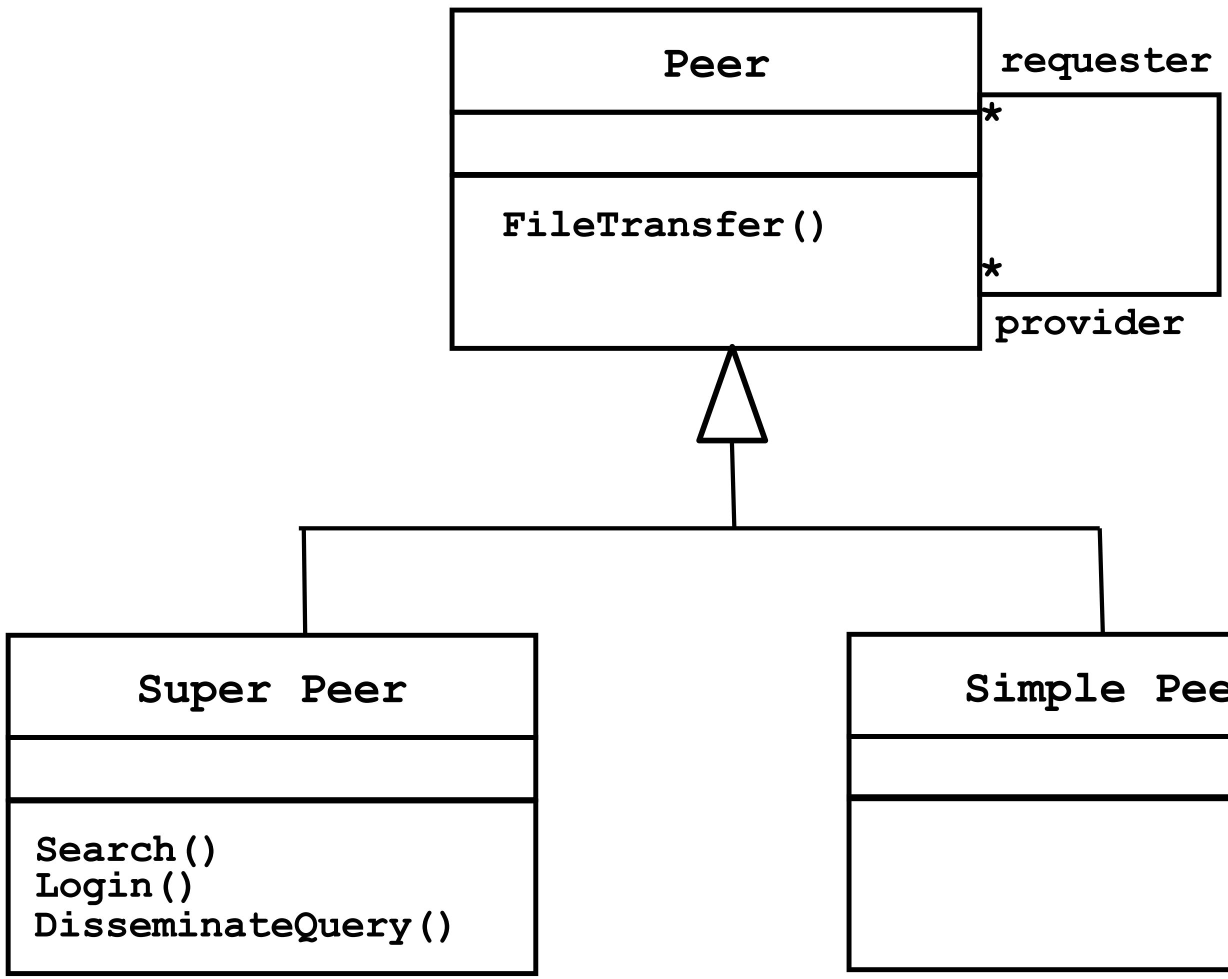
Hybrid: Architecture

- Components:
  - **Peer**
    - An entity with capabilities similar to other entities in the system
    - Each node is both a server and a client
    - Autonomous: no administrative authority
    - Unreliable: nodes enter and leave the network “frequently”
  - **Super Peer**
    - Gathers and stores information about peer and content available for sharing
    - Act as servers to regular peer nodes, peers to other super Peers
    - Maintain indexes to some or all nodes in the system
- Connectors:
  - **Network protocol**
    - Often specialized for P2P communication

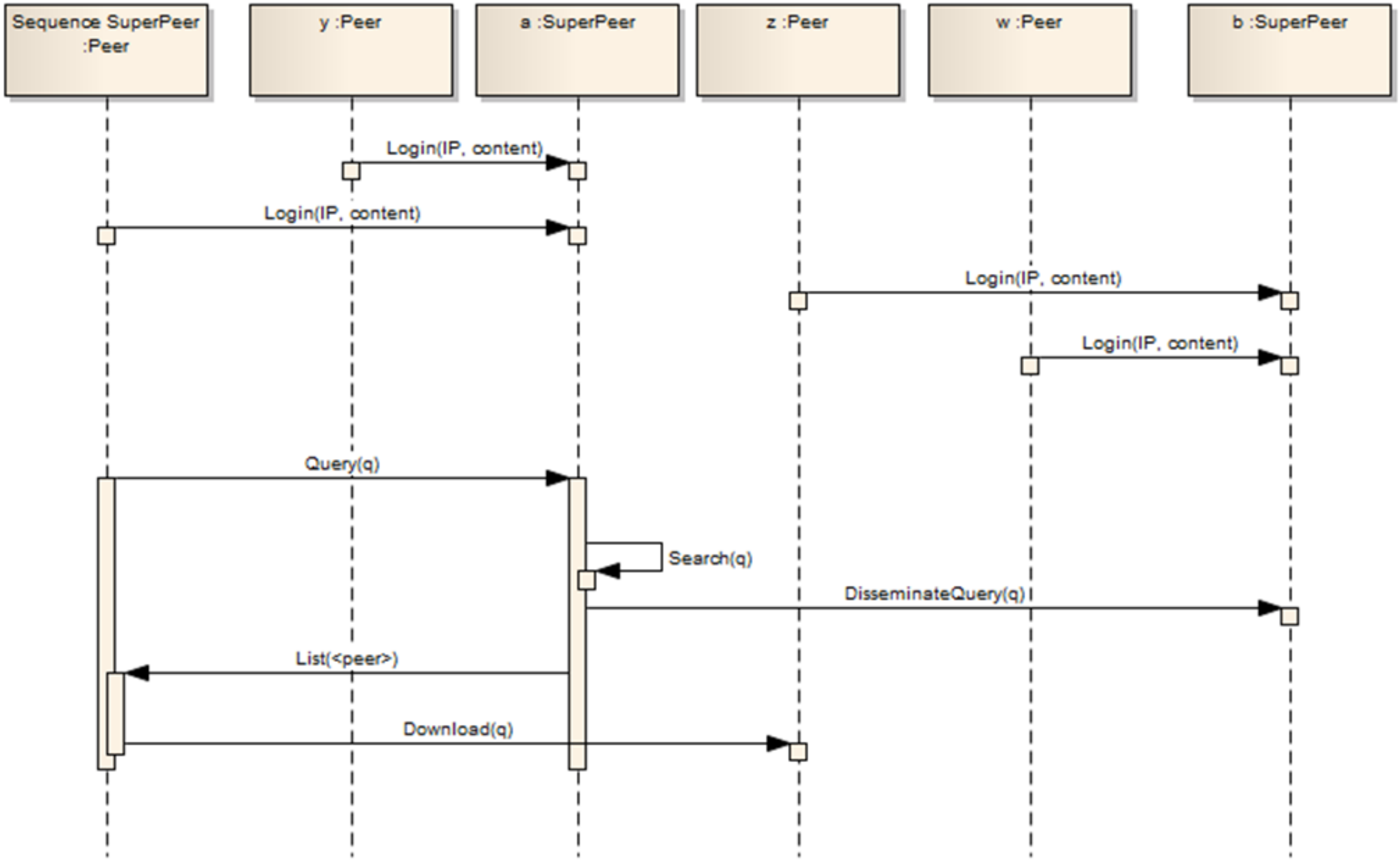
Hybrid Architecture: Component Diagram



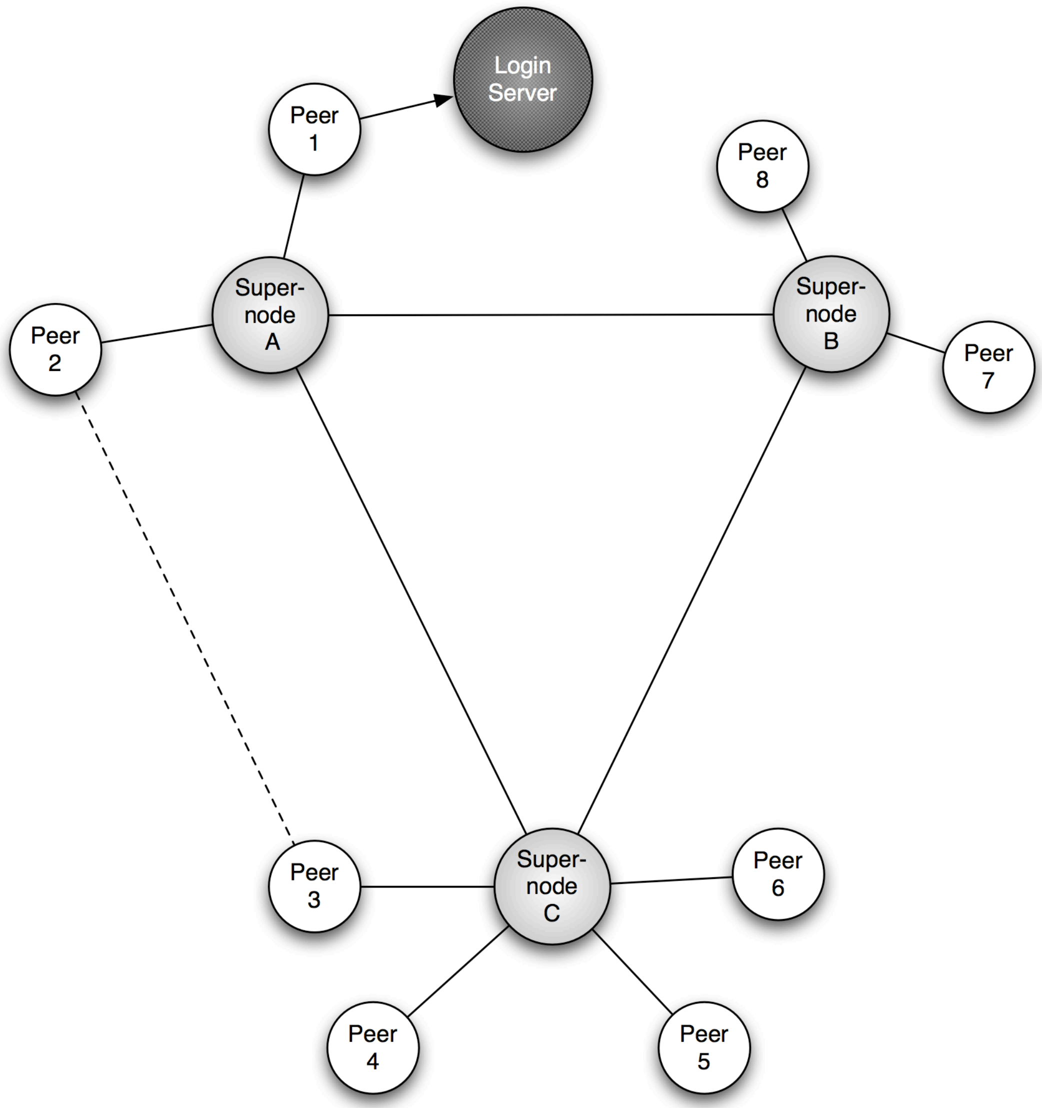
Hybrid Architecture: Class Diagram



Hybrid Architecture: Sequence Diagram



Hybrid Architecture Example: Skype (1)



Hybrid Architecture Example: Skype (2)

- A mixed client-server and peer-to-peer architecture addresses the discovery problem
- Replication and distribution of the directories, in the form of supernodes, addresses the scalability problem and robustness problem encountered in Napster
- Promotion of ordinary peers to supernodes based upon network and processing capabilities addresses another aspect of system performance:
  - “not just any peer” is relied upon for important services

Hybrid Architecture Example: Skype (3)

- A proprietary protocol employing encryption provides privacy for calls that are relayed through supernode intermediaries
- Restriction of participants to clients issued by Skype, and making those clients highly resistant to inspection or modification, prevents malicious clients from entering the network

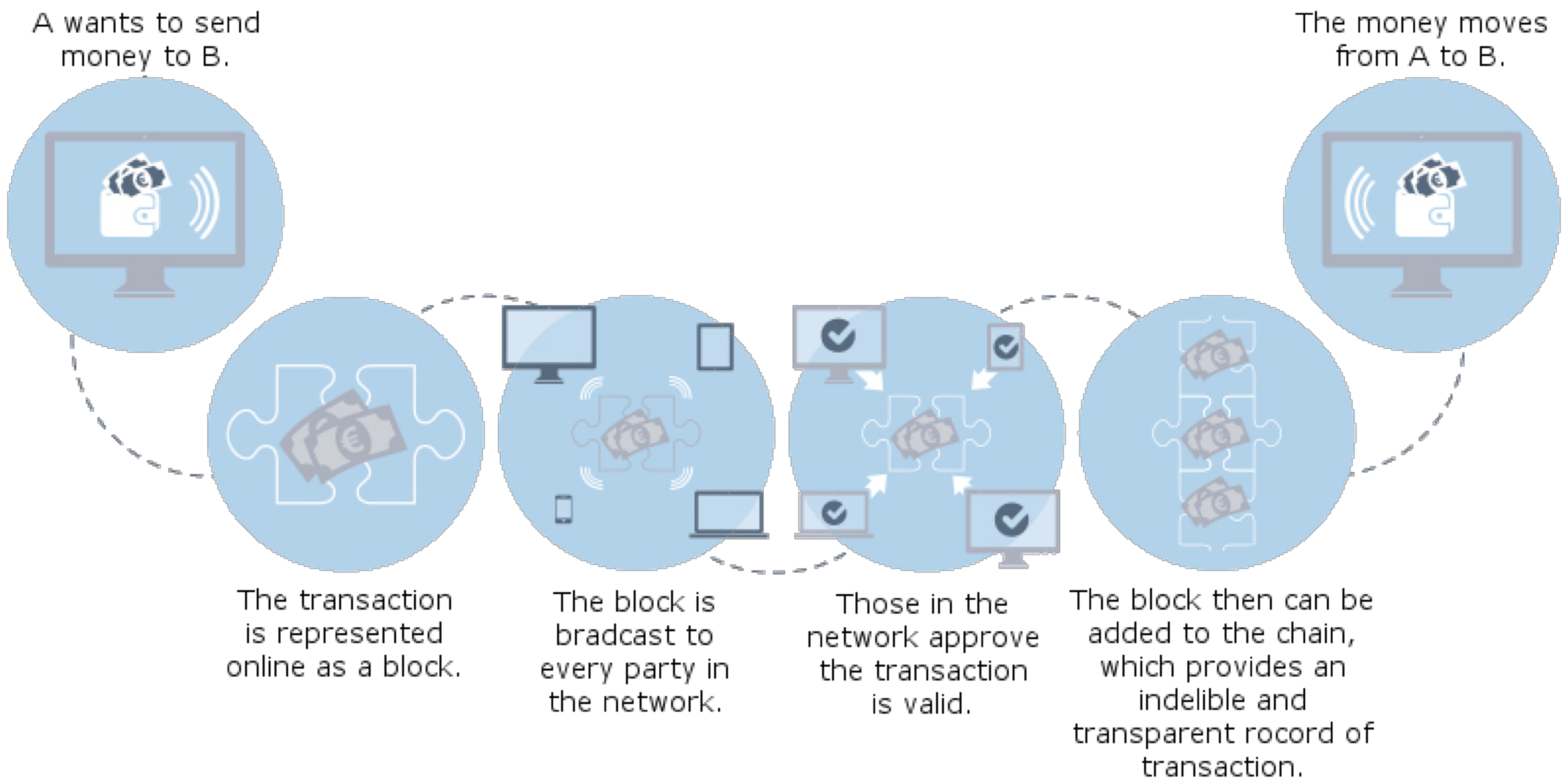
Hybrid Architecture: Pro & Cons

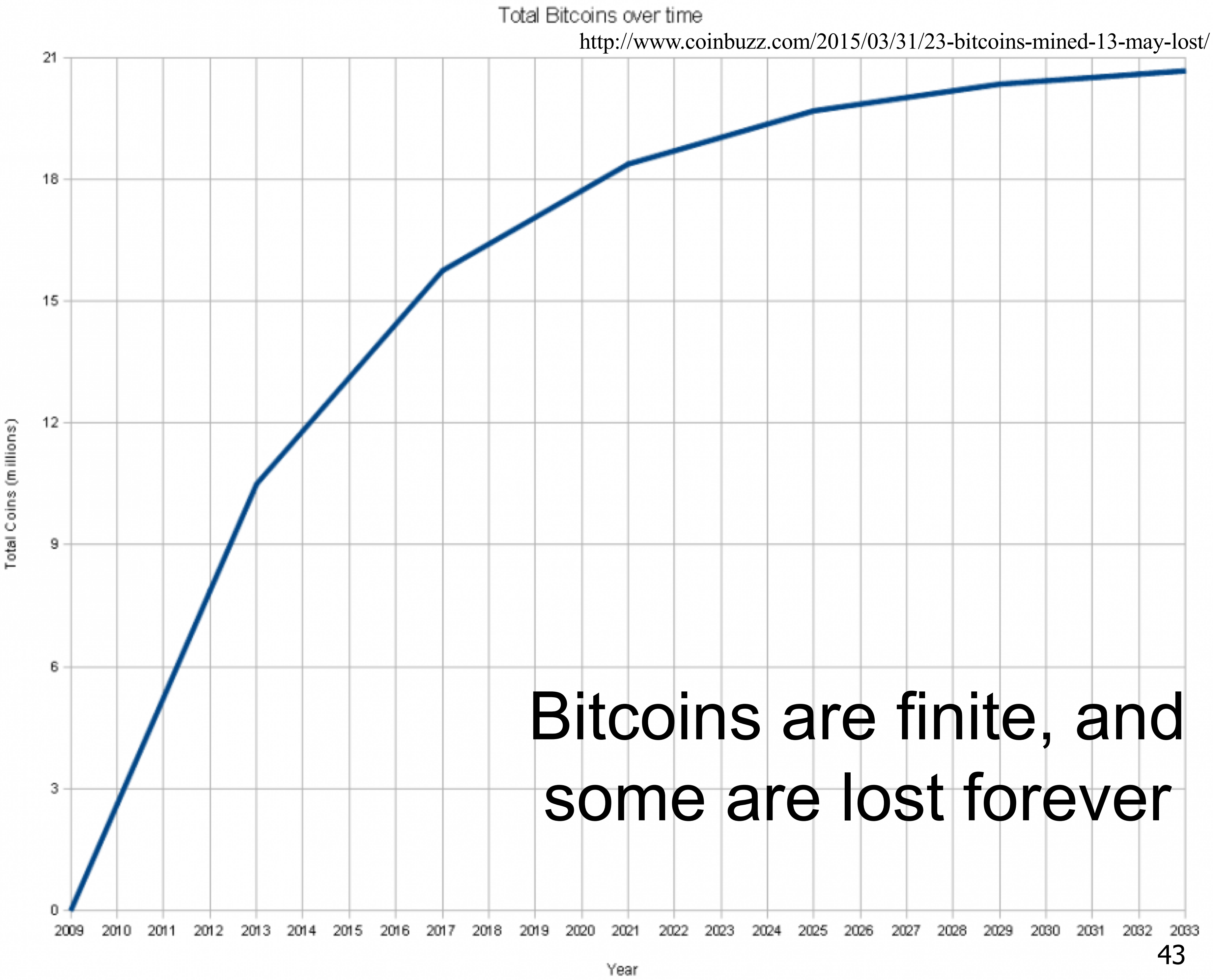
- Benefits:
  - Manageable per-node state
  - Manageable bandwidth usage and time to locate item
  - Guaranteed success
- Pitfalls:
  - Possibly unbalanced load
  - Harder to support fault tolerance

Bitcoins

- Bitcoins are based on the idea of avoiding to let to spend twice the same digital coin using a chain of transactions recorded in a shared ledger
- The Bitcoin system is the blockchain, a P2P architecture, and transactions take place between anonimous users directly, without an intermediary
- These transactions are verified by network nodes and recorded in a public distributed ledger called a blockchain

Bitcoin: dynamics

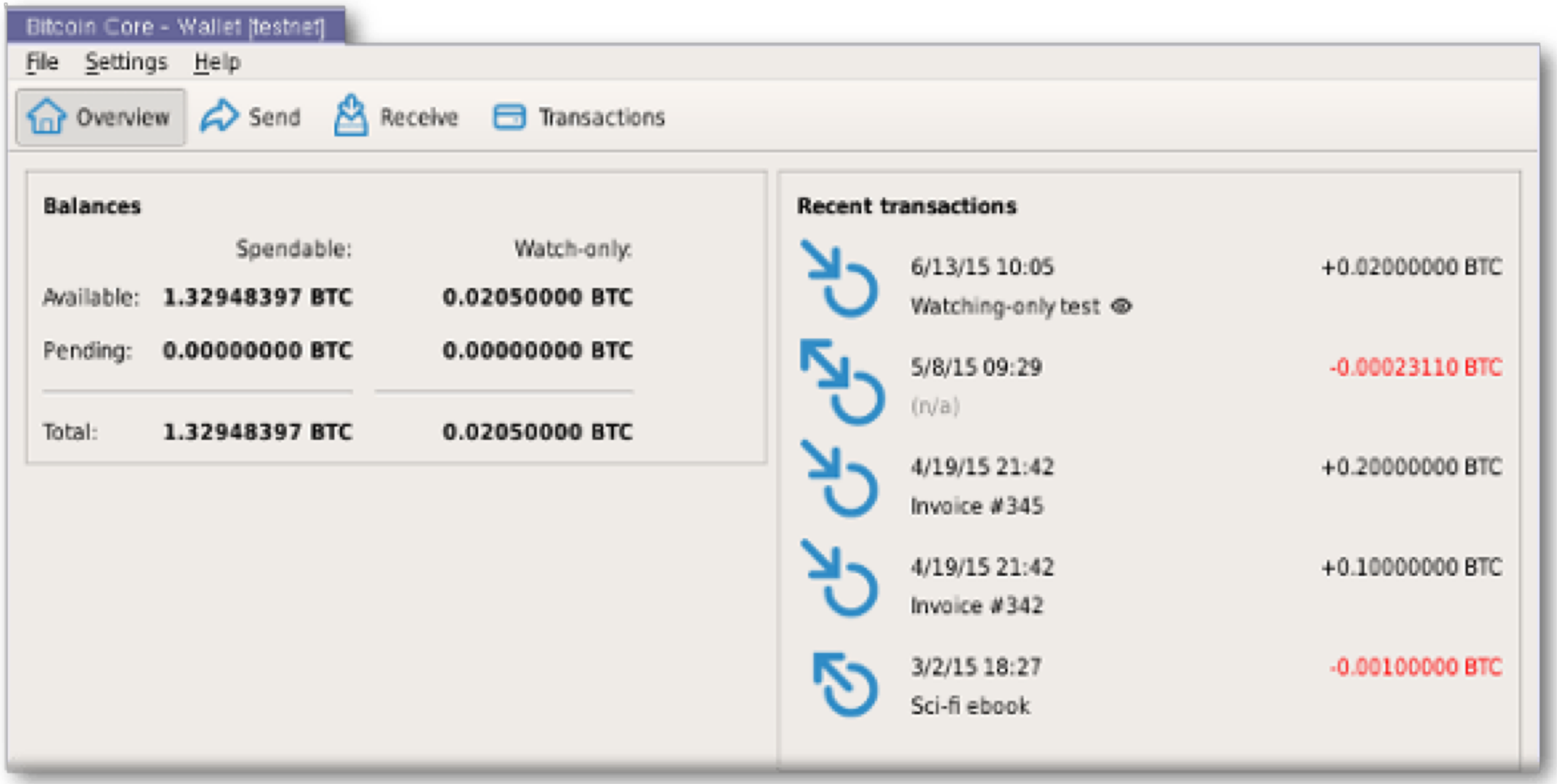




http://www.coinbuzz.com/2015/03/31/23-bitcoins-mined-13-may-lost/

Bitcoins are finite, and some are lost forever

Bitcoin wallet interface



Bitcoin Developer API's Tools for developers to get data about the blockchain

Payment Processing

Receive Payments (My Wallet Account Required)
An incredibly easy method for websites to receive bitcoin payments. This service is completely free and secure. Perfect for business or personal use.

View Documentation

Welcome Developers!
Here you will find everything you need to get started coding for bitcoin. You can use Blockchain.info's own APIs at no cost, to help you create anything bitcoin related! 3rd Party API's provided by other services.

Blockchain Wallet APIs

Blockchain Wallet API (My Wallet Account Required)
API to send and receive payment from a Blockchain Wallet Account.

View Documentation

Web services

Bitcoin-Qt Compatible JSON RPC (My Wallet Account Required)
Blockchain.info is able to function as a bitcoind RPC server for merchants to interact with their My Wallet Account.

View Documentation

Create Wallets
Programmatically create wallets for your users with the ability to load and redeem funds.

View Documentation

Blockchain.info provides official API libraries for a number of languages

Python | Java | .NET (C#) | Ruby | PHP | Node

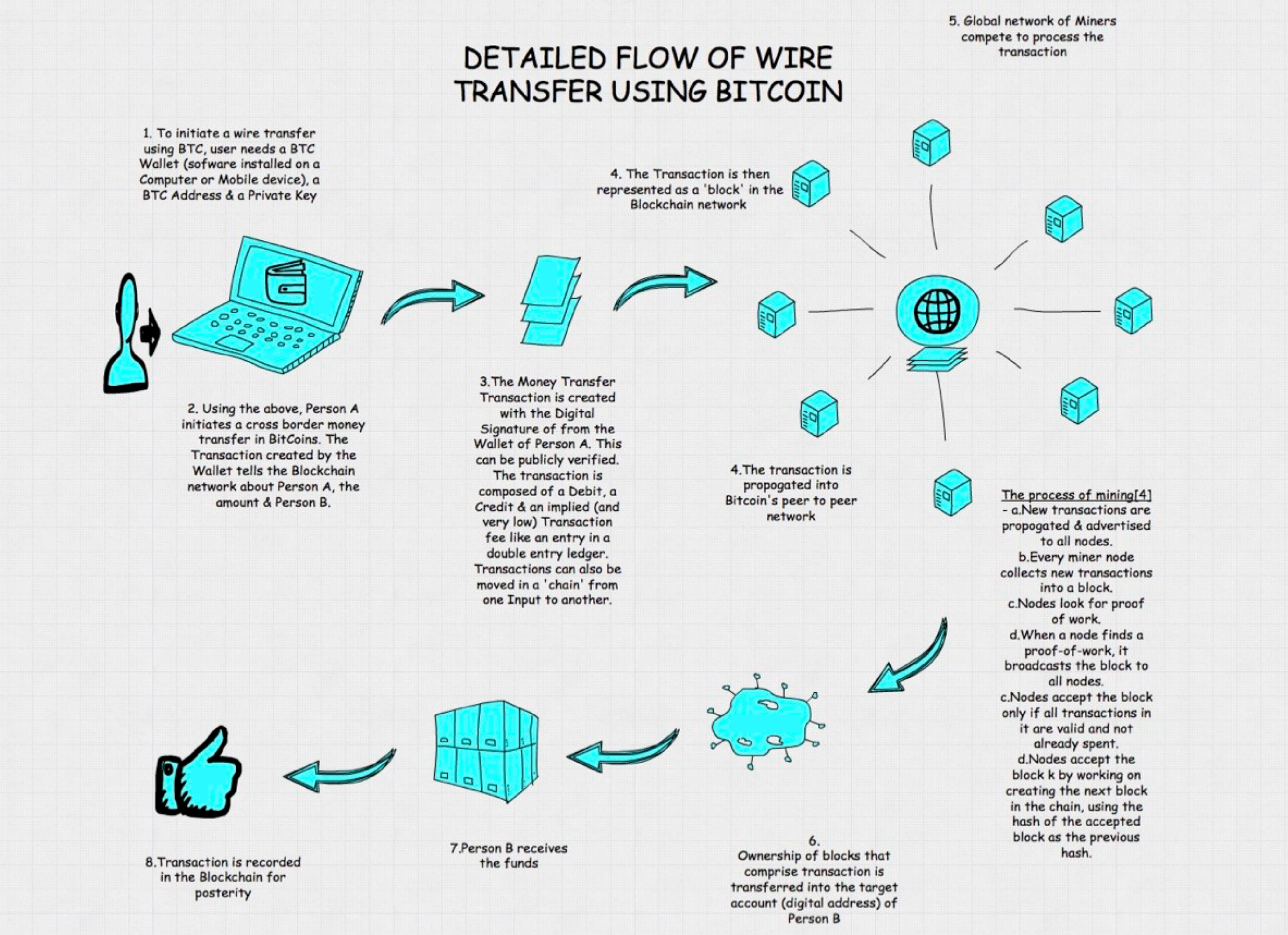
Installation via **pip**:

```
$ pip install blockchain
```

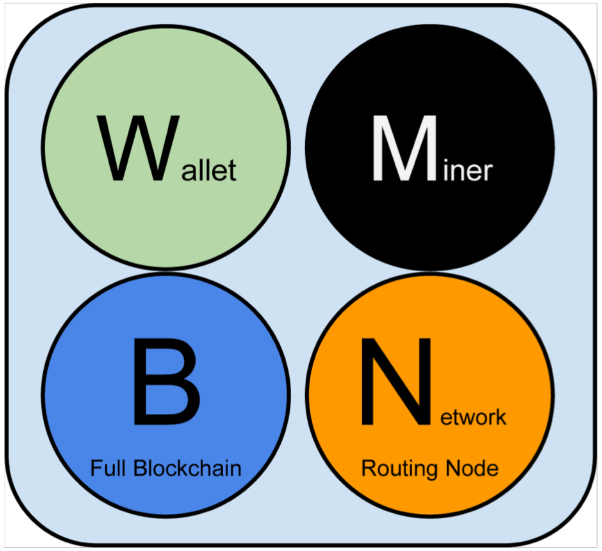
Go to GitHub for documentation and instructions

Data on Transactions & Blocks

Blockchain Data API

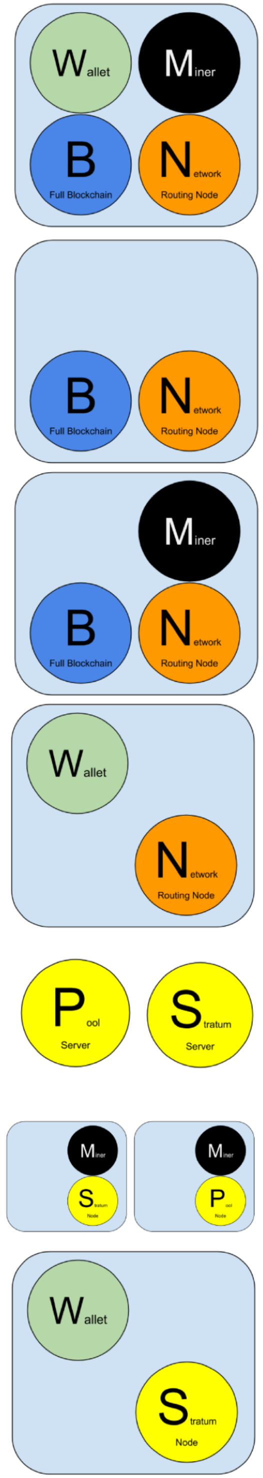

DETAILED FLOW OF WIRE TRANSFER USING BITCOIN
1. To initiate a wire transfer using BTC, user needs a BTC Wallet (sofware installed on a Computer or Mobile device), a BTC Address & a Private Key
2. Using the above, Person A initiates a cross border money transfer in BitCoins. The Transaction created by the Wallet tells the Blockchain network about Person A, the amount & Person B.
3.The Money Transfer Transaction is created with the Digital Signature of from the Wallet of Person A. This can be publicly verified. The transaction is composed of a Debit, a Credit & an implied (and very low) Transaction fee like an entry in a double entry ledger. Transactions can also be moved in a 'chain' from one Input to another.
4. The Transaction is then represented as a 'block' in the Blockchain network
4.The transaction is propogated into Bitcoin's peer to peer network
5. Global network of Miners compete to process the transaction
The process of mining[4] - a.New transactions are propogated & advertised to all nodes. b.Every miner node collects new transactions into a block. c.Nodes look for proof of work. d.When a node finds a proof-of-work, it broadcasts the block to all nodes. c.Nodes accept the block only if all transactions in it are valid and not already spent. d.Nodes accept the block k by working on creating the next block in the chain, using the hash of the accepted block as the previous hash.
6. Ownership of blocks that comprise transaction is transferred into the target account (digital address) of Person B
7.Person B receives the funds
8.Transaction is recorded in the Blockchain for posterity

Bitcoin nodes



Bitcoin node: main functions

http://chimera.labs.oreilly.com/books/1234000001802/ch06.html



Reference Client (Bitcoin Core)

Contains a Wallet, Miner, full Blockchain database, and Network routing node on the bitcoin P2P network.

Full Block Chain Node

Contains a full Blockchain database, and Network routing node on the bitcoin P2P network.

Solo Miner

Contains a mining function with a full copy of the blockchain and a bitcoin P2P network routing node.

Lightweight (SPV) wallet

Contains a Wallet and a Network node on the bitcoin P2P protocol, without a blockchain.

Pool Protocol Servers

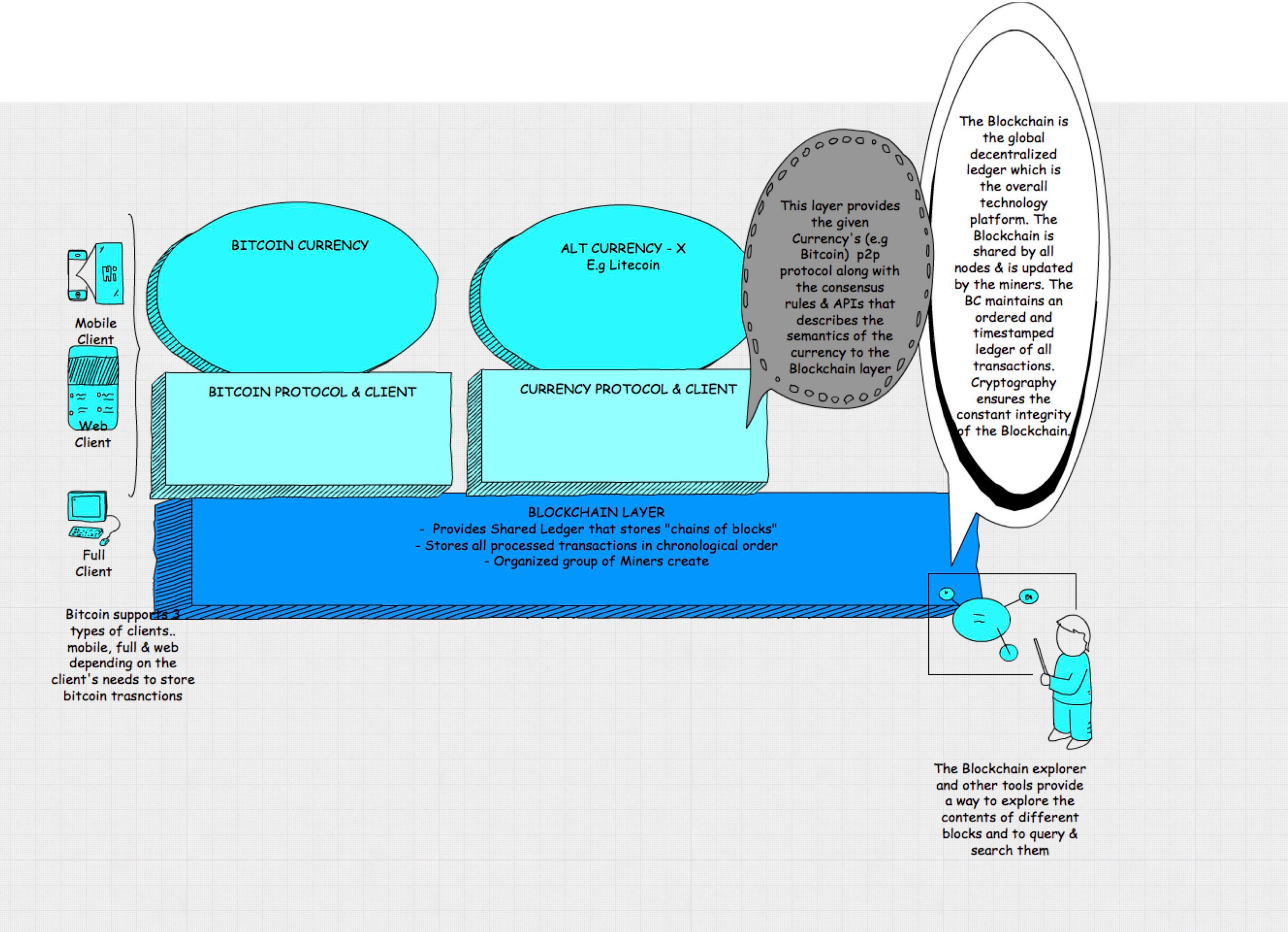
Gateway routers connecting the bitcoin P2P network to nodes running other protocols such as pool mining nodes or Stratum nodes.

Mining Nodes

Contain a mining function, without a blockchain, with the Stratum protocol node (S) or other pool (P) mining protocol node.

Lightweight (SPV) Stratum wallet

Contains a Wallet and a Network node on the Stratum protocol, without a blockchain.



Mobile Client
Web Client
Full Client
Bitcoin supports 3 types of clients.. mobile, full & web depending on the client's needs to store bitcoin trasnctions
BITCOIN CURRENCY
ALT CURRENCY - X
E.g Litecoin
BITCOIN PROTOCOL & CLIENT
CURRENCY PROTOCOL & CLIENT
This layer provides the given Currency's (e.g Bitcoin) p2p protocol along with the consensus rules & APIs that describes the semantics of the currency to the Blockchain layer
The Blockchain is the global decentralized ledger which is the overall technology platform. The Blockchain is shared by all nodes & is updated by the miners. The BC maintains an ordered and timestamped ledger of all transactions. Cryptography ensures the constant integrity of the Blockchain.
BLOCKCHAIN LAYER
- Provides Shared Ledger that stores "chains of blocks"
- Stores all processed transactions in chronological order
- Organized group of Miners create
The Blockchain explorer and other tools provide a way to explore the contents of different blocks and to query & search them

Bitnodes

GLOBAL BITCOIN NODES DISTRIBUTION

Reachable nodes as of Tue Nov 28 2017 18:55:10 GMT+0100 (CET).

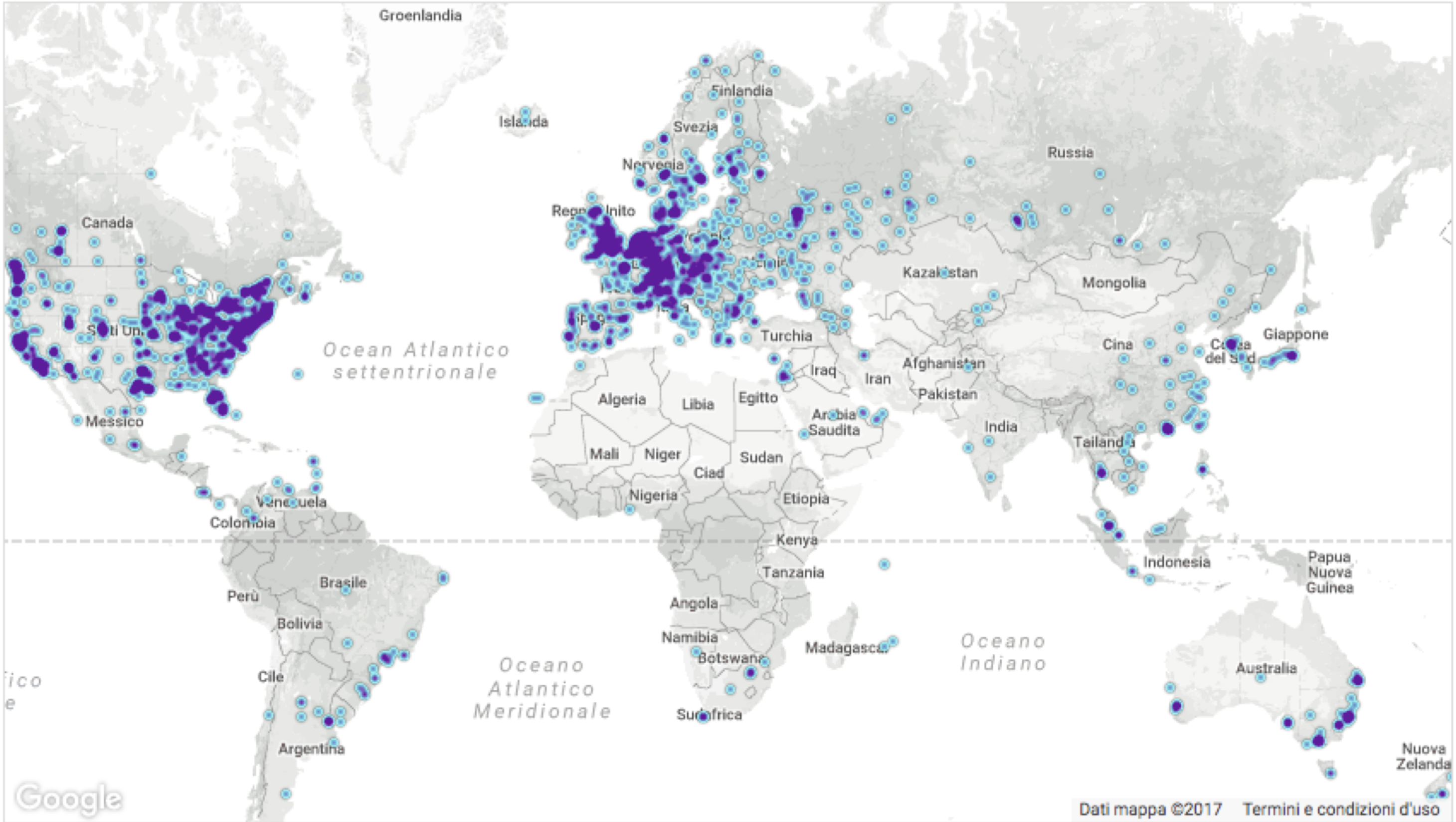
11311 NODES

24-hour charts »

Top 10 countries with their respective number of reachable nodes are as follow.

RANK	COUNTRY	NODES
1	United States	3202 (28.31%)
2	Germany	1875 (16.58%)
3	France	767 (6.78%)
4	China	687 (6.07%)
5	Netherlands	537 (4.75%)
6	Canada	475 (4.20%)
7	United Kingdom	446 (3.94%)
8	n/a	388 (3.43%)
9	Russian Federation	376 (3.32%)
10	Singapore	237 (2.10%)

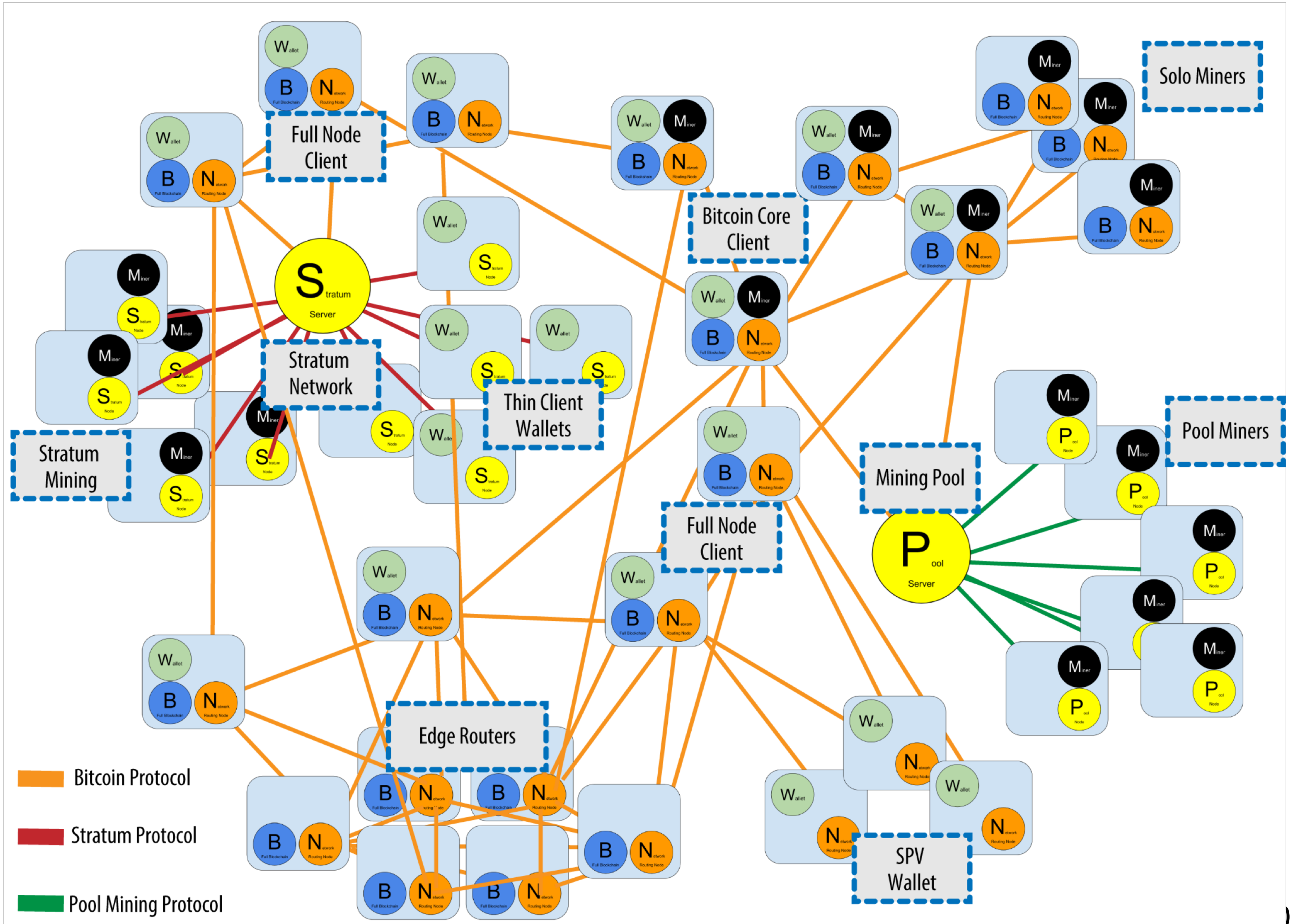
More (100) »



Map shows concentration of reachable Bitcoin nodes found in countries around the world.

LIVE MAP

Bitcoin architecture

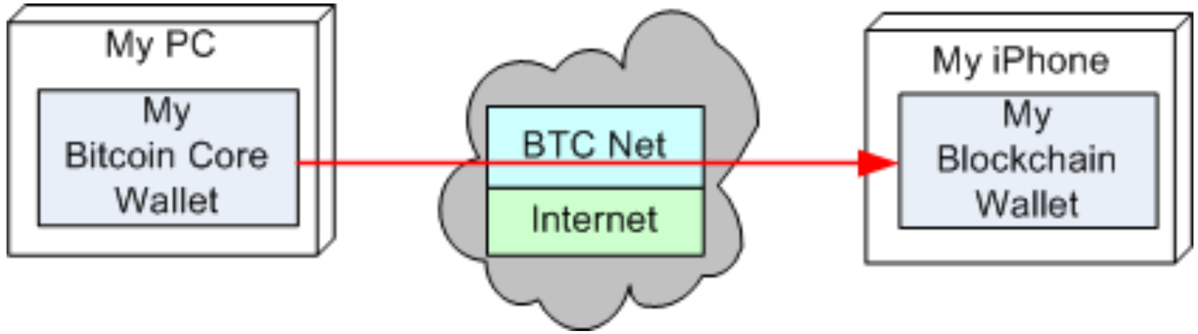


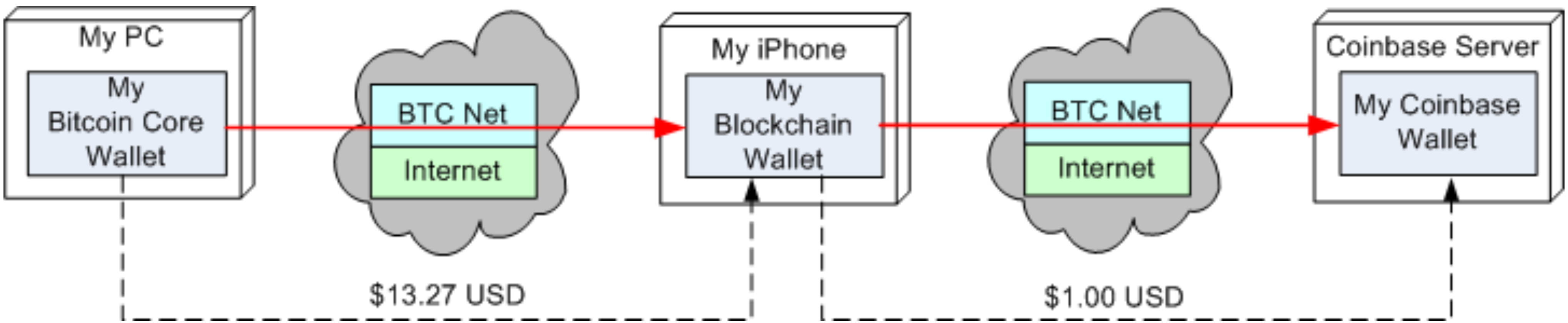
Anonimity

- Bitcoin addresses are not tied to people
- Transactions are not tied to people
- Transaction data is transmitted to a random subset of nodes

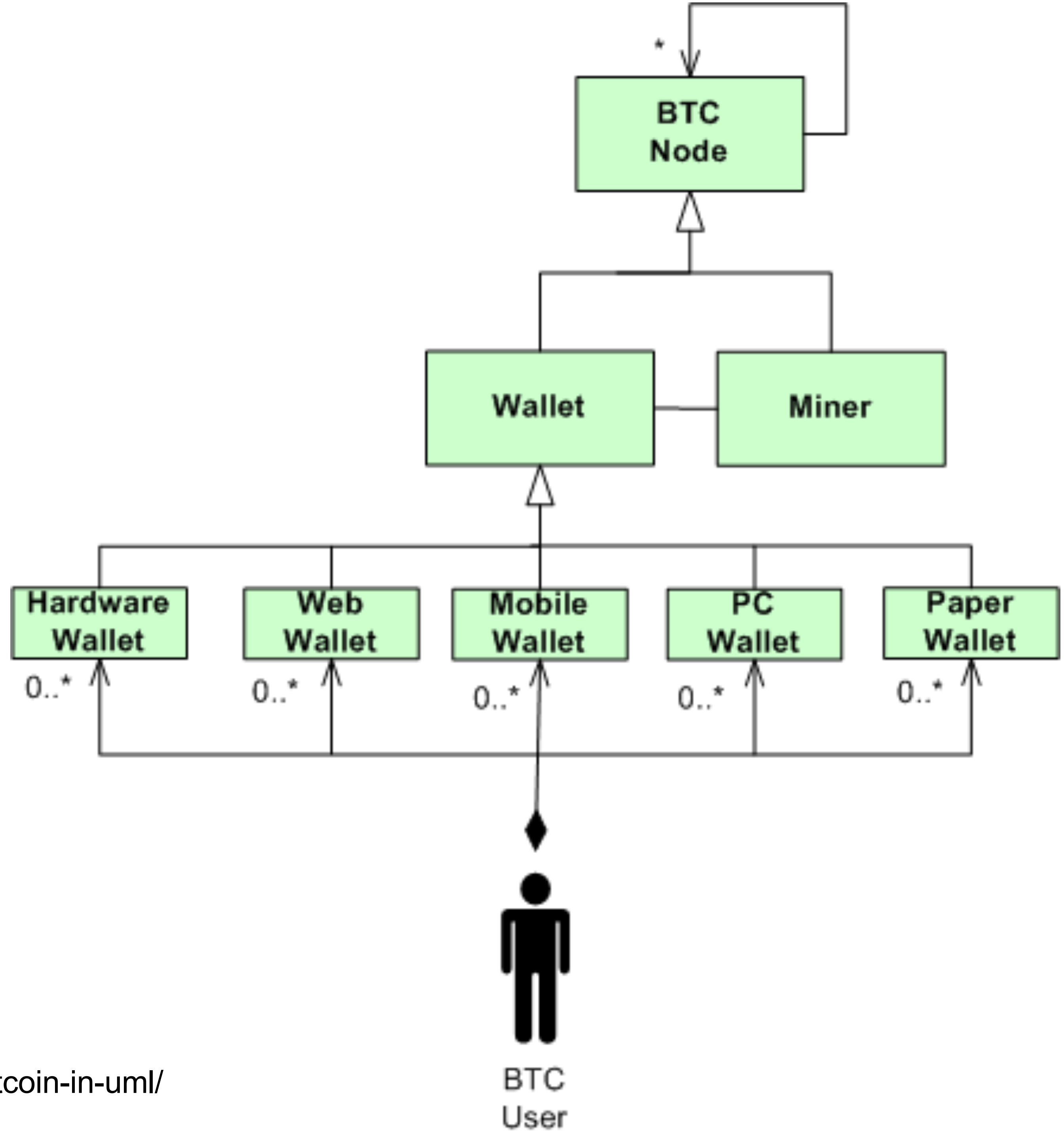
- However, there are some (expensive) methods to de-anonymize a user, so Bitcoin is not perfectly anonymous

Moving bitcoins between wallets

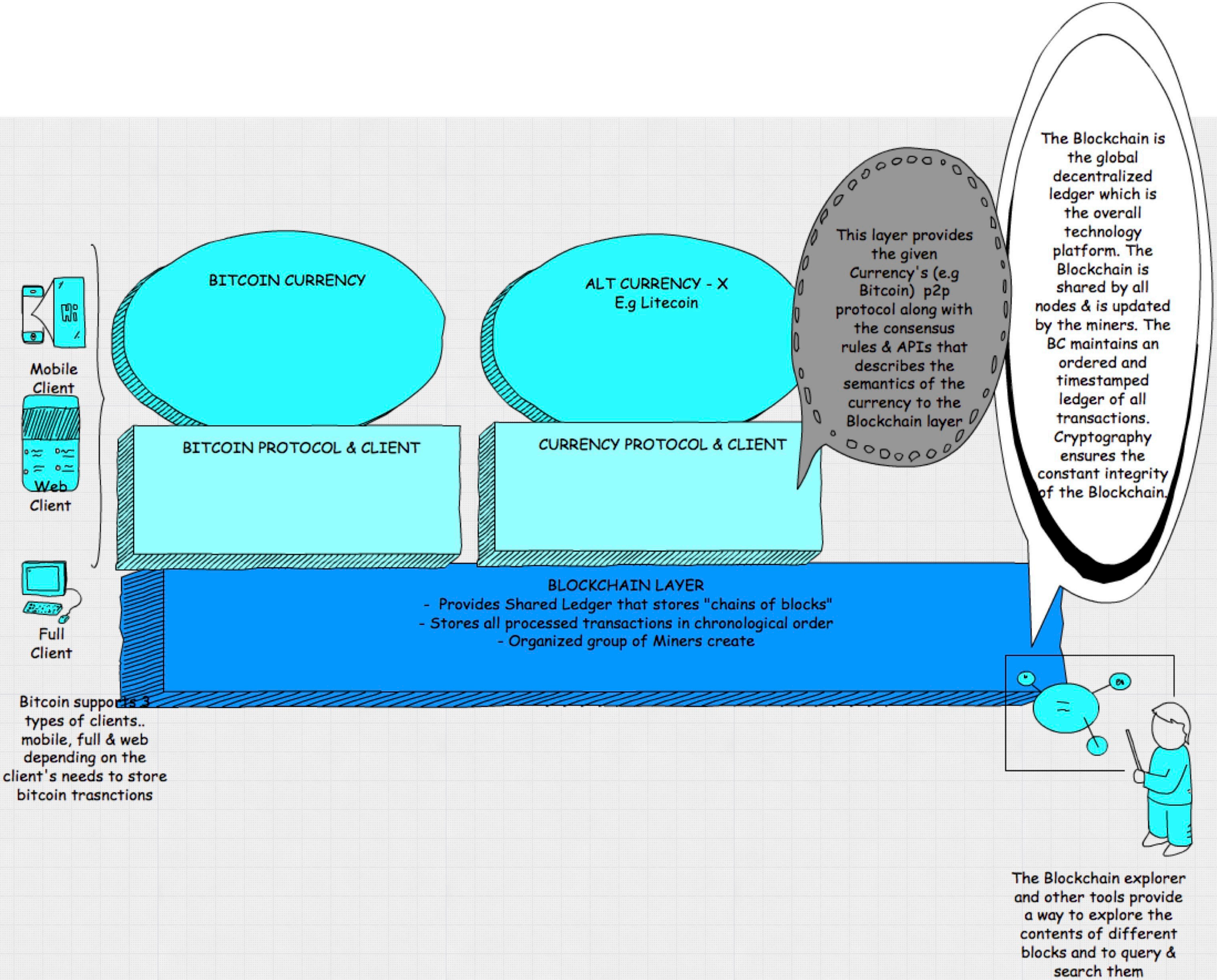




Bitcoin

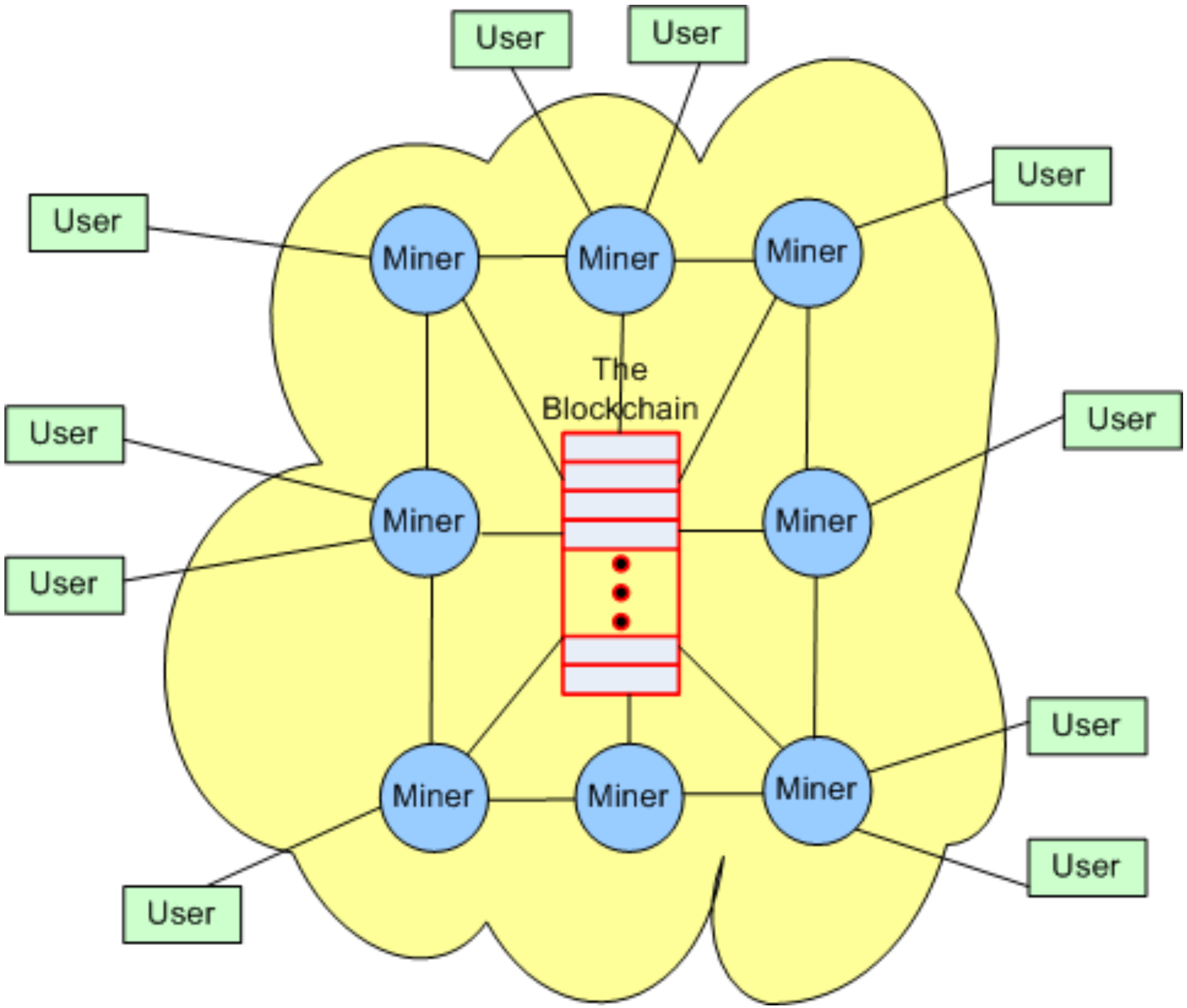


https://bulldozer00.com/2015/10/25/bitcoin-in-uml/



Mobile Client
Web Client
Full Client
Bitcoin supports 3 types of clients.. mobile, full & web depending on the client's needs to store bitcoin trasnctions
BITCOIN CURRENCY
ALT CURRENCY - X
E.g Litecoin
BITCOIN PROTOCOL & CLIENT
CURRENCY PROTOCOL & CLIENT
This layer provides the given Currency's (e.g Bitcoin) p2p protocol along with the consensus rules & APIs that describes the semantics of the currency to the Blockchain layer
The Blockchain is the global decentralized ledger which is the overall technology platform. The Blockchain is shared by all nodes & is updated by the miners. The BC maintains an ordered and timestamped ledger of all transactions. Cryptography ensures the constant integrity of the Blockchain.
BLOCKCHAIN LAYER
- Provides Shared Ledger that stores "chains of blocks"
- Stores all processed transactions in chronological order
- Organized group of Miners create
The Blockchain explorer and other tools provide a way to explore the contents of different blocks and to query & search them

Blockchain



User
User
User
User
Miner
Miner
Miner
The
Blockchain
User
User
Miner
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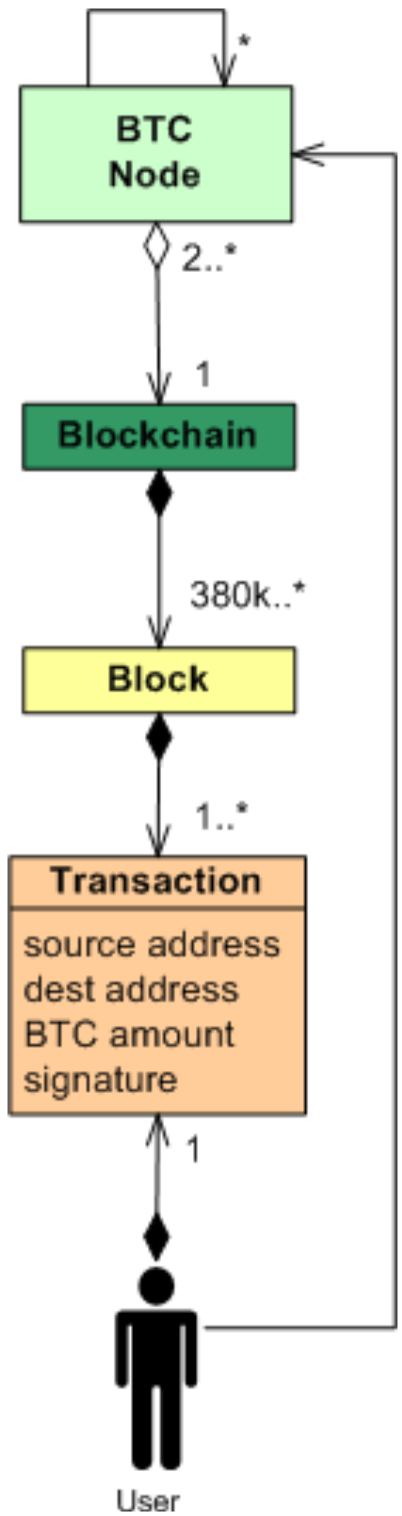
User
User

Implementing bitcoins: blockchain

- Each bitcoin (BTC) node retains a copy of the global, publicly shared blockchain.
- the Blockchain has 380K+ Blocks.
- Each Block has one or more validated BTC Transactions embedded within it.
- Via the interface facilities provided by a BTC Node, a User composes a Transaction and submits it to the network for validation and execution.
- Each instance of a BTC Transaction contains a source address, destination address, the BTC amount to be transacted, and the source address owner's signature.



Bitcoin vs Ethereum

- Since the sw infrastructure is open source, it is easy to develop new cryptocurrencies
- The difference between Bitcoin and Ethereum is that Bitcoin is a currency, whereas Ethereum is a ledger technology.
- Both Bitcoin and Ethereum operate on the "blockchain", however Ethereum is more robust.
- Ethereum supports the building of decentralized applications – *smart contracts*

Smart contracts are agents

- A smart contract is a set of promises, specified in digital form, including protocols within which the parties perform on these promises
- A smart contract is a general purpose computation that takes place on a blockchain
- The bitcoin is limited to the currency use case; ethereum replaces bitcoin's restrictive language (a scripting language of a hundred scripts) and replaces allowing developers to write their own programs
- Smart contracts are similar to autonomous agents

Conclusions

- P2P networks are quite old: the Internet is a P2P
- Several new applications are implemented as p2p
- Blockchains are a powerful architecture for innovative financial applications

Self test

- Which architectural drives support P2P applications?
- What is an overlay network?
- What is the relationship between p2p and C/S?
- What is a hybrid p2p system?
- What is a blockchain?

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Useful resources

- http://www.disruptivetelephony.com/2010/11/a-brief-primer-on-the-tech-behind-skype-p2psip-and-p2p-networks.html
- https://en.bitcoin.it/wiki/Help:FAQ
- http://www.vamsitalkstech.com/?cat=2
- https://www.theverge.com/2013/12/19/5183356/how-to-steal-bitcoin-in-three-easy-steps
- https://github.com/ethereum/wiki/wiki/White-Paper

Questions?