Why use just one computer? (An intro to Distributed Systems)

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Advancing Technology for Humanity

On the menu

- I’ve got a system. Is it distributed?
- How processes communicate
- Multicast
- Hands-on!
- Final thoughts

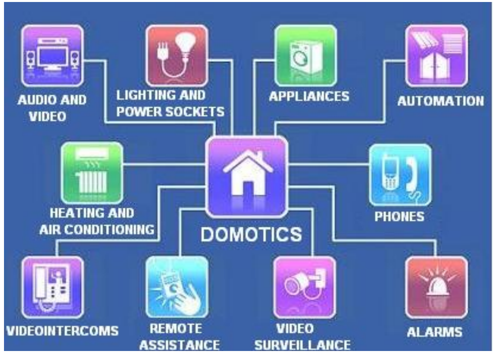
I’ve got a system. Is it distributed?

Symptoms of a distributed system:

- Your system has **more than one process**
- Your system’s processes (can) **run on different computers**
- Your system’s processes **communicate with each other** (via messages)

Distributed systems in the wild

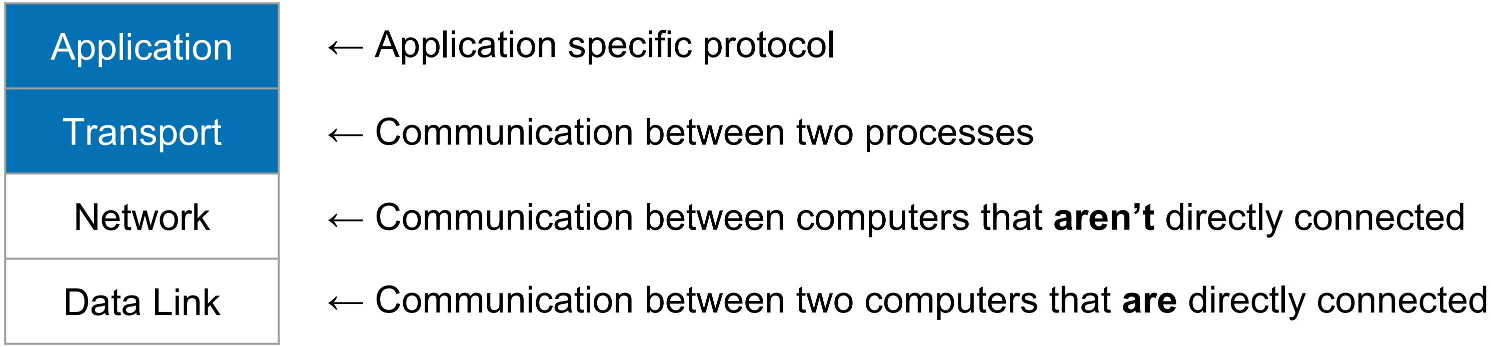
- The web and the internet
- E-mail
- ATM networks
- P2P applications (bittorrent and others)
- Swarm robotics
- IoT
- Autonomous driving
- Blockchain
- ...



Message
Network
Medium
Medium
Devices

How processes communicate

In distributed systems, **communication is key**. Different computers can’t really cooperate if they don’t understand how to talk to each other.



Application ← Application specific protocol

Transport ← Communication between two processes

Network ← Communication between computers that **aren’t** directly connected

Data Link ← Communication between two computers that **are** directly connected

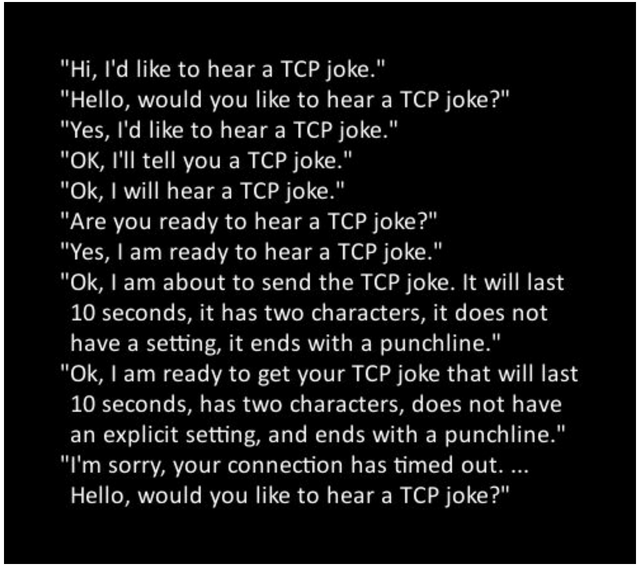
How processes communicate - Transport Layer

The two big transport layer protocols:

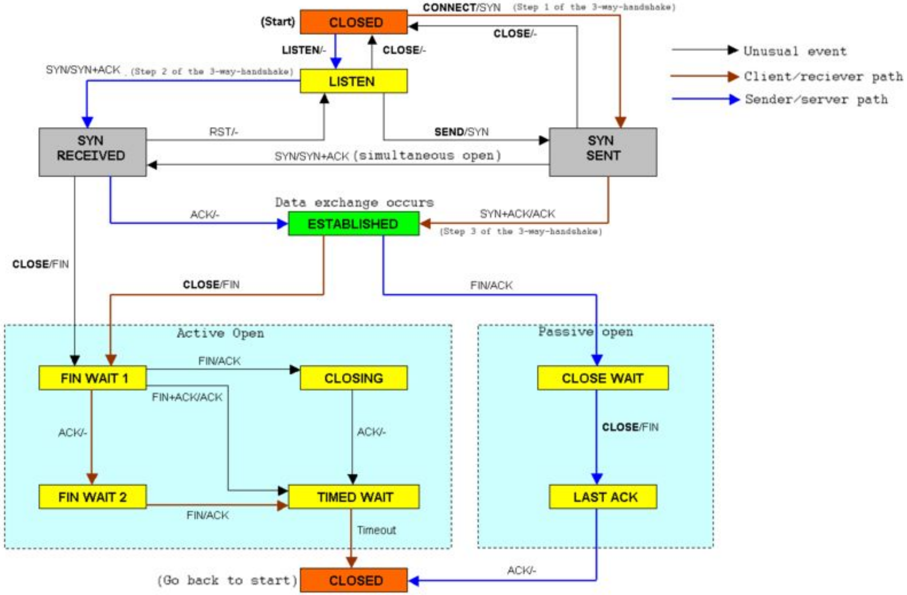
	UDP	TCP
Connection setup	No	Yes
Order	No	Yes
Reliability	No	Yes
Flow Control	No	Yes
Endpoints	*	1

How processes communicate - Transport Layer

Connection setup:



"Hi, I'd like to hear a TCP joke."
"Hello, would you like to hear a TCP joke?"
"Yes, I'd like to hear a TCP joke."
"OK, I'll tell you a TCP joke."
"Ok, I will hear a TCP joke."
"Are you ready to hear a TCP joke?"
"Yes, I am ready to hear a TCP joke."
"Ok, I am about to send the TCP joke. It will last 10 seconds, it has two characters, it does not have a setting, it ends with a punchline."
"Ok, I am ready to get your TCP joke that will last 10 seconds, has two characters, does not have an explicit setting, and ends with a punchline."
"I'm sorry, your connection has timed out. ... Hello, would you like to hear a TCP joke?"



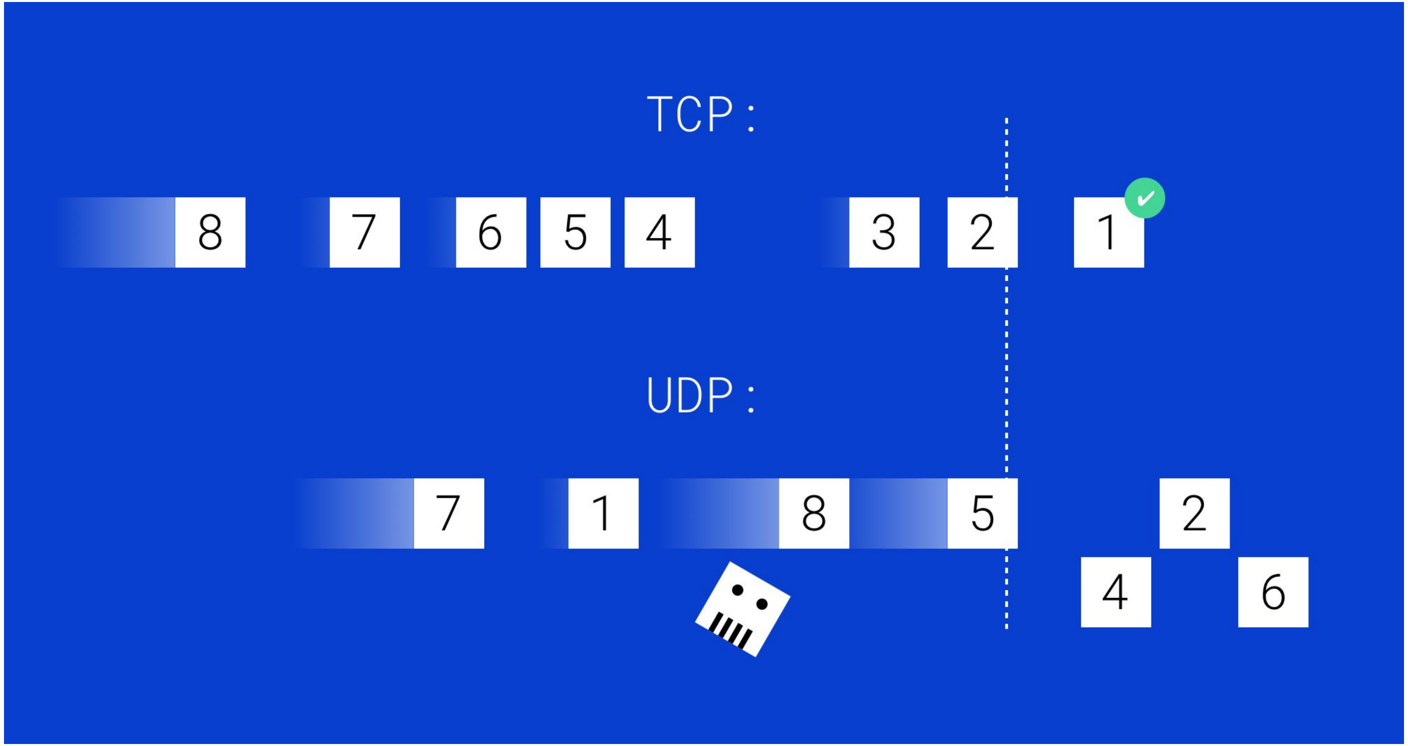
How processes communicate - Transport Layer

Connection Setup - Advantages:

- More information = more control
  - Can ensure flow control
  - Can ensure order
  - Can ensure delivery
- Provides some security

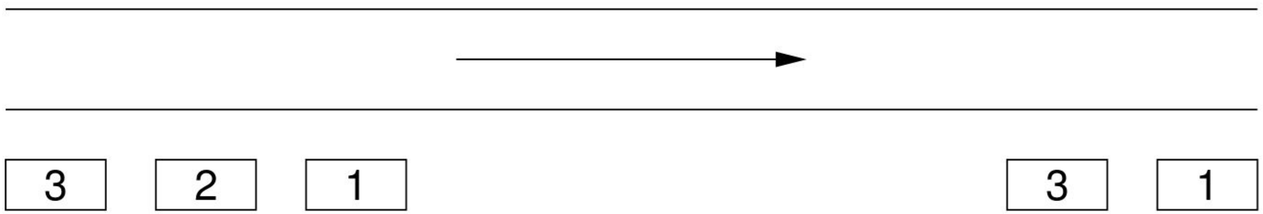
How processes communicate - Transport Layer

Order:

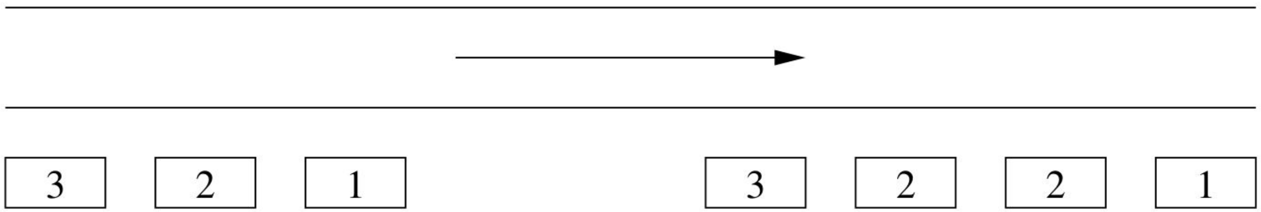


How processes communicate - Transport Layer

Reliability - Packet loss:

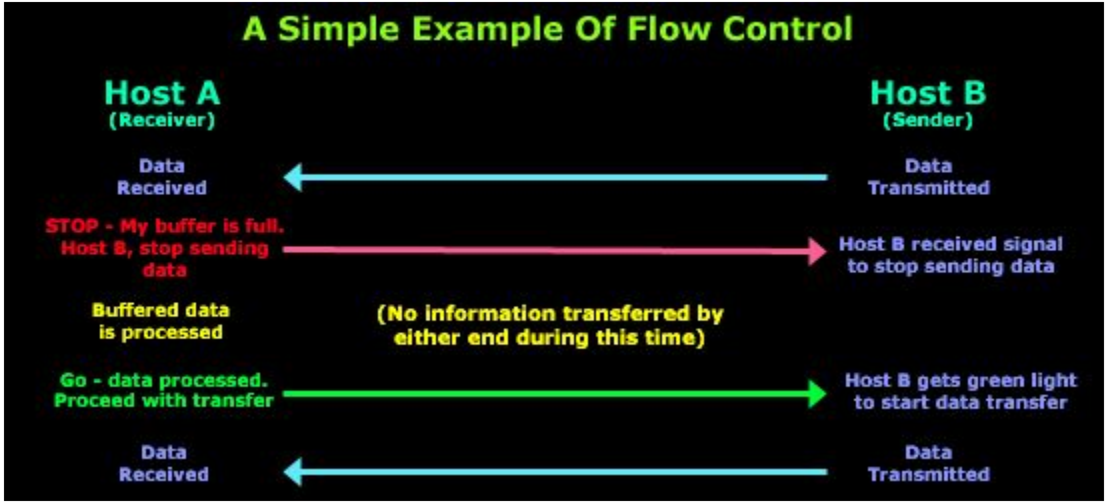


Reliability - Packet duplication:



How processes communicate - Transport Layer

Flow control:



A Simple Example Of Flow Control

Host A
(Receiver)

Host B
(Sender)

Data Received ← Data Transmitted

STOP - My buffer is full. Host B, stop sending data → Host B received signal to stop sending data

Buffered data is processed

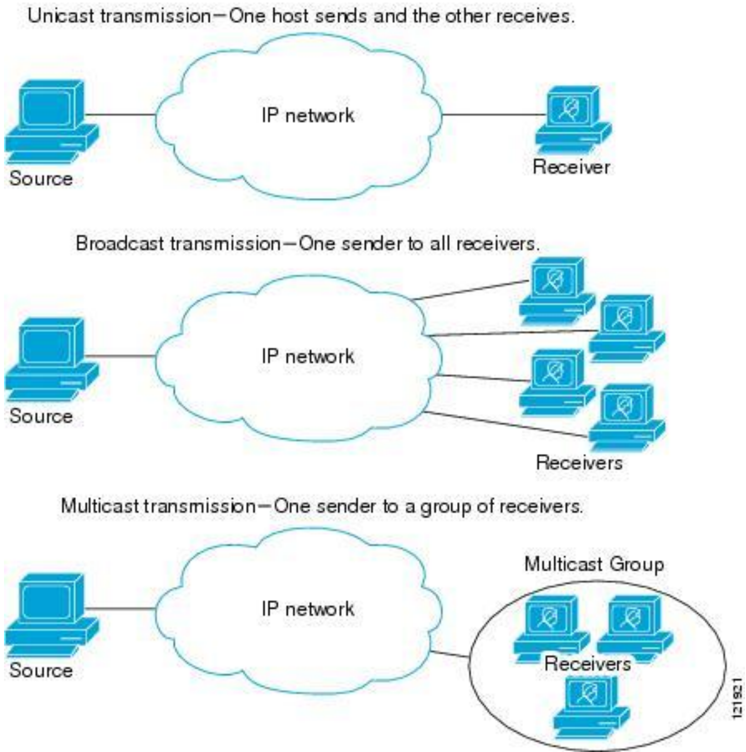
(No information transferred by either end during this time)

Go - data processed. Proceed with transfer → Host B gets green light to start data transfer

Data Received ← Data Transmitted

How processes communicate - Transport Layer

Endpoints:


Unicast transmission–One host sends and the other receives.
IP network
Source
Receiver
Broadcast transmission–One sender to all receivers.
IP network
Source
Receivers
Multicast transmission–One sender to a group of receivers.
Multicast Group
IP network
Source
Receivers
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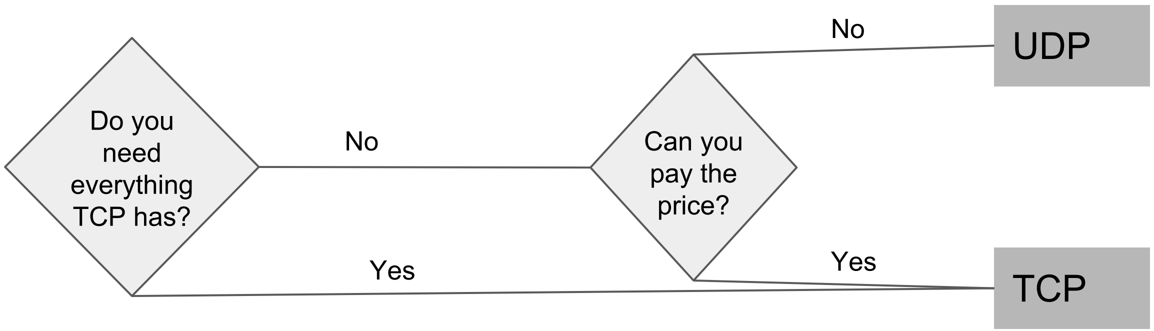
How processes communicate - Transport Layer

How to choose the transport protocol for your application:



How processes communicate - Application Layer

Here is where you can really define your system’s way of communicating. You can design your protocol any way you want, but there are some useful frameworks:

- Binary
- Text
- JSON
- XML

Multicast

- IP Multicast
- Application-level Multicast

Multicast

Multicast: A naïve implementation

- N senders
- M receivers
- N*M single-ended channels
- M messages must be sent for each message
- Same message will probably traverse the same link multiple times
- The sender needs to know all of its receivers

Multicast

IP Multicast

- Use a spanning tree containing the sender, all receivers and all nodes in between them
- The sender does everything as if it were doing unicast
- Receivers **subscribe** to the multicast group to be added to the spanning tree
- They can also **unsubscribe** to be removed
- IP multicast can only be used within the same network and using UDP
  - Reliable multicast is **hard**
  - ISPs don’t provide multicast cross-networks
  - IPv6 supposedly does!

Multicast

Application-level Multicast

- Build an overlay network
- Can use spanning tree
- Alternatively use epidemic algorithms

Hands-on!

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Final thoughts

So, why use just one computer?

- It’s simpler
- You don’t need your processes to be on different computers
- You don’t even have multiple processes
- Distributed systems are a pain in the a**!

Multicast

Why are distributed systems even a thing?

- They enable communication (potentially) without spatial boundaries
- They enable collaborative work across multiple systems
- They allow for bigger systems
- Spreading functionality may be useful!
    - Redundancy
    - Sharding
    - Divide-and-conquer algorithms
    - Partial anonimity

What now?

This workshop was just the tip of the iceberg.

- Remote Method Invocation (RMI)
- Cryptography
- Name resolution
- Serverless features
- Synchronization
- Fault Tolerance
- Consensus
- Atomic commitment