What is a distributed system?

“A distributed system is one in which the failure of a computer you didn’t even know existed can render your own computer unusable.”

Leslie Lamport
**Openness**
- Easily interact with other open systems
- Conform to well-defined interfaces
- Achieve independence in heterogeneity wrt Hardware, Platform, Languages
- Support different app/user-specific policies

**Transparency**

<table>
<thead>
<tr>
<th>Transparency</th>
<th>Description</th>
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<tbody>
<tr>
<td>Access</td>
<td>Hides differences in data representation and invocation mechanism</td>
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<tr>
<td>Location</td>
<td>Hides where an object resides</td>
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<tr>
<td>Migration</td>
<td>Hides from an object to another object</td>
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<td>Relocation</td>
<td>Hides from a client to the location of an object to which the client is bound</td>
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<tr>
<td>Replication</td>
<td>Hides that an object may be replicated, with replicas at different locations</td>
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<td>Concurrency</td>
<td>Hides coordination of activities between objects</td>
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<td>Failure</td>
<td>Hides the failure and recovery of an object</td>
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<td>Persistence</td>
<td>Hides whether a resource is in memory or on disk</td>
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**Scalability**
- **Size scalability**
  - number of users and processes
- **Geographical scalability**
  - maximum distance between nodes
- **Administrative scalability**
  - number of administrative domains

*ideally, provide only mechanisms!*
A first course in Distributed Computing...

- Two basic approaches
- cover many interesting systems, and distill from them fundamental principles
- focus on a deep understanding of the fundamental principles, and see them instantiated in a few systems

A few intriguing questions

- How do we talk about a distributed execution?
- Can we draw global conclusions from local information?
- Can we coordinate operations without relying on synchrony?
- For the problems we know how to solve, how do we characterize the “goodness” of our solution?
- Are there problems that simply cannot be solved?
- What are useful notions of consistency, and how do we maintain them?
- What if part of the system is down? Can we still do useful work? What if instead part of the system becomes “possessed” and starts behaving arbitrarily: All bets are off?
Two Generals’ Problem

Problem: Save Western Civilization (i.e., design a protocol that ensures Romans always attack simultaneously)

- only communication is by messenger
- messengers must sneak through the valley
- they don’t always make it

Claim: There is no non-trivial protocol that guarantees that the Romans will always attack simultaneously

Proof: Let $P$ be shortest such protocol
- consider last message $m_{\text{last}}$
- $P$ must work if $m_{\text{last}}$ never arrives
- so don’t send it
- but now we have a new protocol shorter than $P$!

Fundamental Limitation: Solution needs
- unbounded number of messages or
- guaranteed message delivery

Otherwise, attack may never take place!