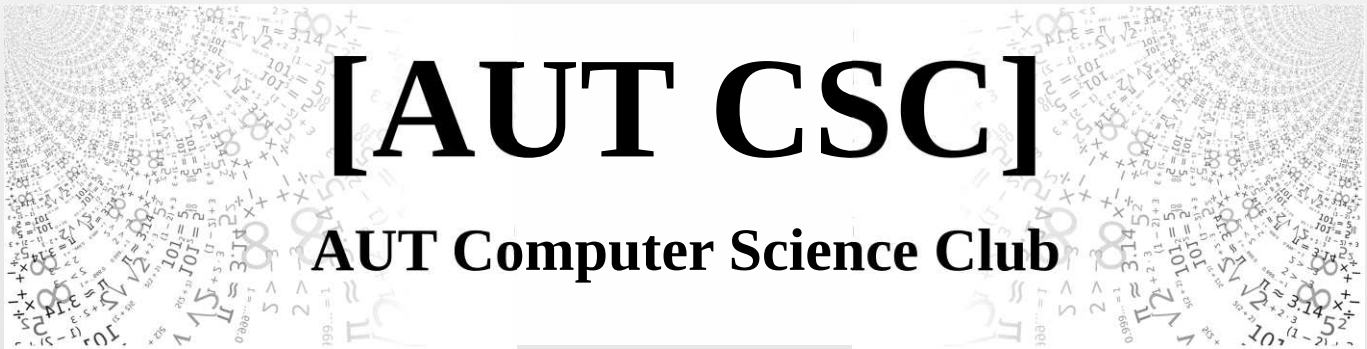
The Two Generals Problem

Or: Why distributed systems are Nintendo Hard



Koz Ross

March 16, 2017

Overview

Introduction to distributed systems

The Two Generals Problem

Consequences

Questions

Introduction to distributed systems

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Systems which are not distributed are called otherwise, *singular* (or *centralized* in some contexts).

Examples of distributed systems

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- Unreliable communication (timelines can go out of sync, trending posts can vary, updates might be lost or take a long time)

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- Unreliable communication (peers randomly join and leave, network failure to particular peers, slow connections. . .)

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This shows that distributed systems don't just apply to computing!

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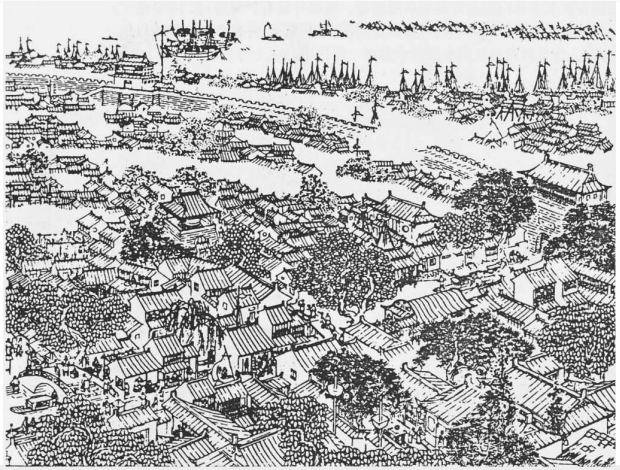
The alternative to understanding distributed systems is *awful* (look at AWS and Github, and that's just recently!).

The Two Generals Problem

Problem overview



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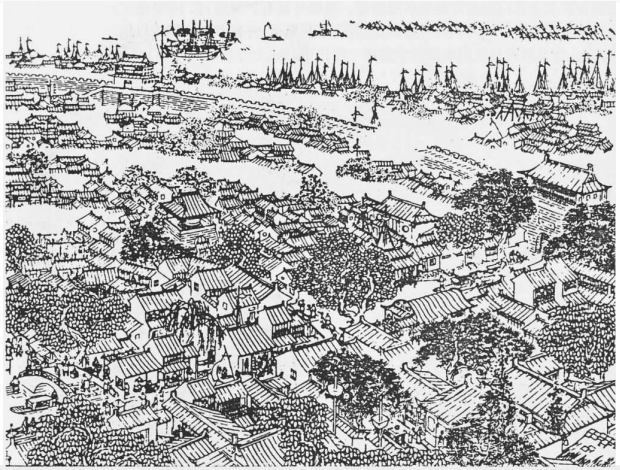


Both generals *must* attack at the same time if they want to take the city.

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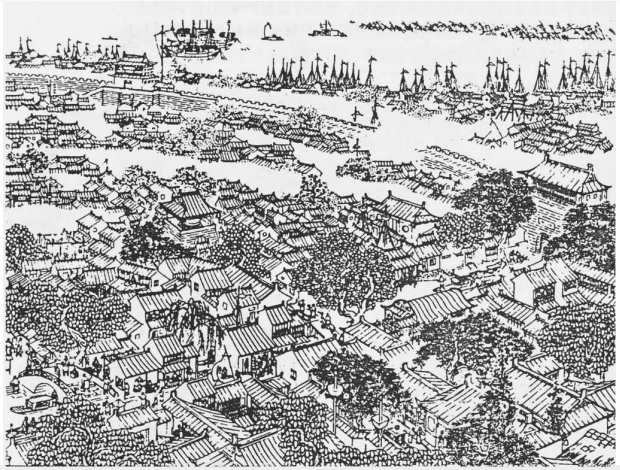

Both generals *must* attack at the same time if they want to take the city. However, they haven't agreed on a time before they set up camp.

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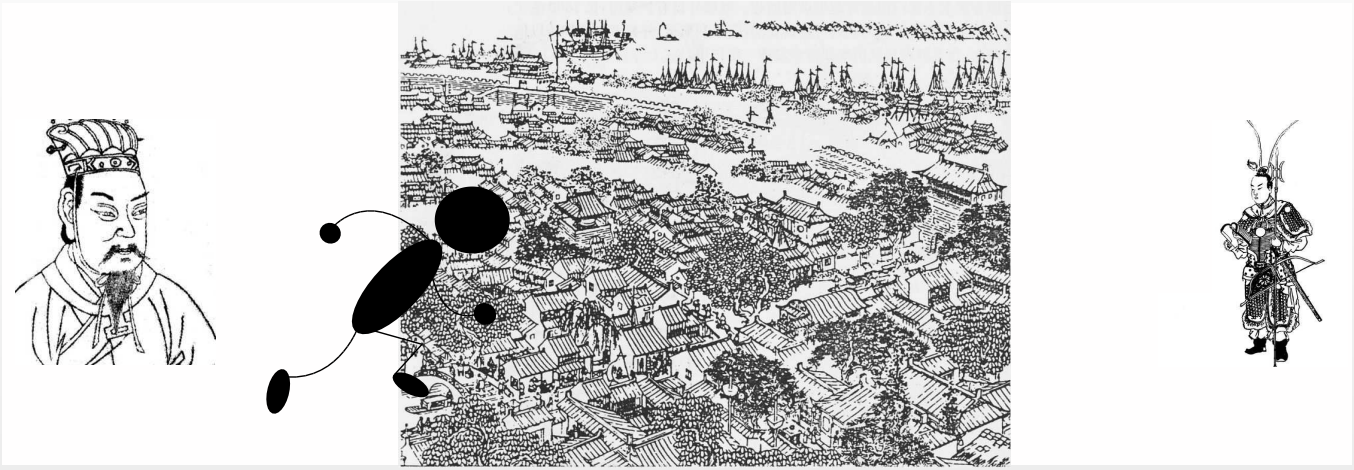

The only way the generals can communicate with each other is by sending messengers between their camps.

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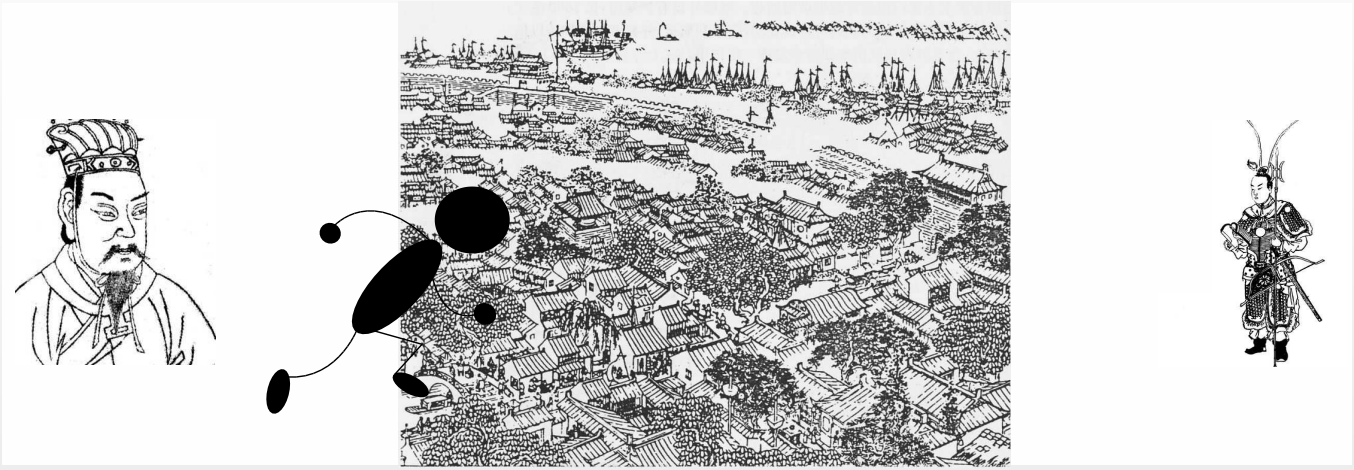

The only way the generals can communicate with each other is by sending messengers between their camps. In order for the messengers to get there in a timely manner, they must run through the city.

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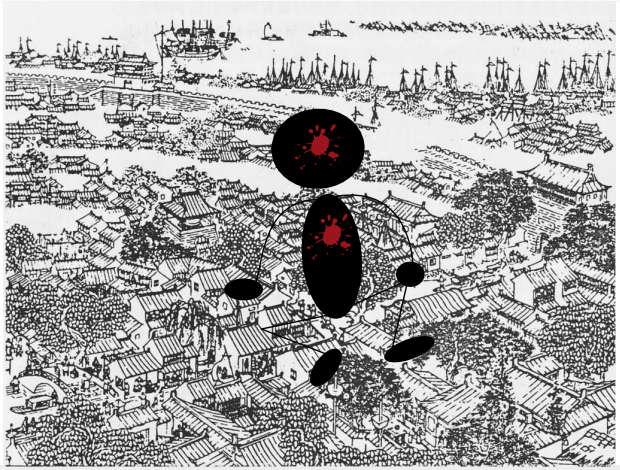

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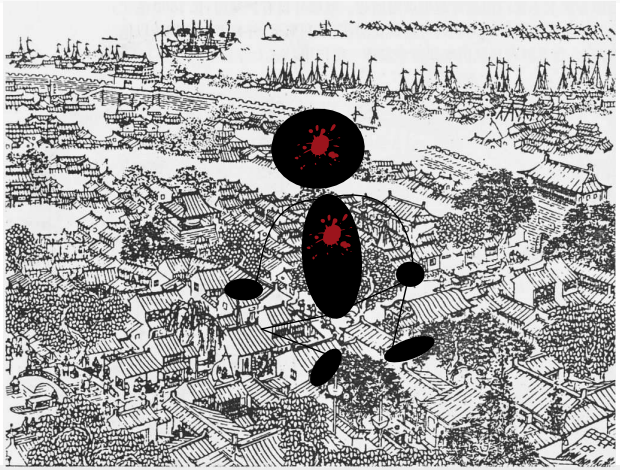

Some messengers won't make it. Thus, neither general knows which of their messages got delivered, or what the chance of any given message getting delivered is.

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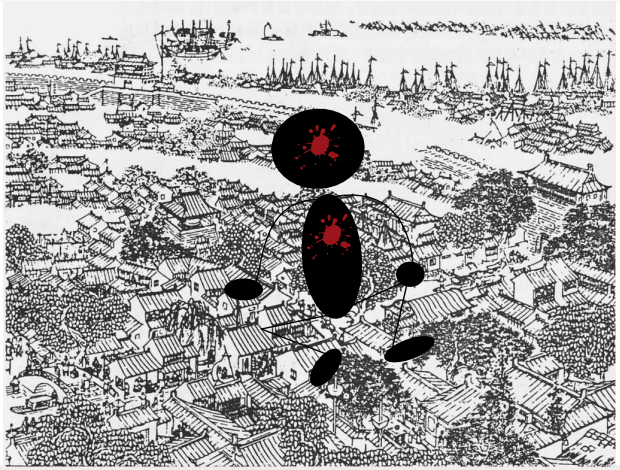

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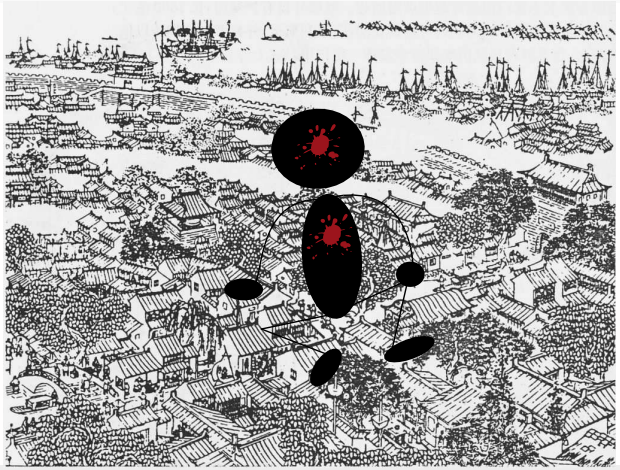


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We will refer to our generals as C and L (for no particular reason whatsoever).

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We say that our generals have *reached agreement* if:

- $d(C) \neq \mathrm{undef}$ and $d(L) \neq \mathrm{undef}$; and
- $d(C) = d(L)$

Problem statement

Theorem. *There is no* $\mathrm{out}(C), \mathrm{out}(L)$ *such that* C, L *are guaranteed to reach agreement with probability 1.*

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Note that this does *not* claim that we cannot *ever* reach agreement — only that we can't be certain that we will, given only the outboxes of both generals.

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This is intentional: if nobody's sent any messages, clearly nobody's made any decisions, and thus, nobody's agreed to anything.

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As m is an arbitrary message, it follows that we can reach agreement when $\mathrm{out}(C) = \mathrm{out}(L) = \emptyset$. However, this is a contradiction, as by definition, this is impossible. Thus, no such $\mathrm{out}(C), \mathrm{out}(L)$ can exist. □

Consequences

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- A lot of work on singular systems is next-to-worthless for distributed ones.
- There are lots of ways to obtain coherency and agreement in distributed systems, but *none* will be as perfect as a singular one (although you might not care in some cases).

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- Know your tradeoffs — if you can avoid needing a lot of synchronization or information sharing, definitely avoid it, or at least limit its impact.
- Understand what the computer scientists have said about distributed systems — it's not nearly as theoretical as you think, and it might save your job one day.

A final thought

> *"You know you have a distributed system when the crash of a computer you've never heard of stops you from getting any work done."*
>
> Leslie Lamport

Questions