Demystifying Networking: Teaching Non-Majors via Analogical Problem-Solving

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What is analogical problem solving?

There are two companies A and B, located in cities about 200 km apart. The CEO of company A wants to send a document, of 100 pages, to the CEO of company B.

How can this be done, given the following constraints:

- There is no email, no fax, no phone, no post office - no form of modern communication whatsoever.
- The only means of communication are messenger boys.
- The messenger boys are weak. Each can carry only 10 pages at a time!
- The messenger boys are fickle. They may decide to quit without notice at any, even while carrying pages!

What do such problems have to do with ...

- The other terms in our paper title:
  - Demystifying Networking
  - Teaching Non-Majors

- How is the CEO problem (previous slide) relevant to learning Computer Networking?
- What is the point of solving it?

- → Focus of this talk

Typical networking course

- Developed with CS majors as the target audience.
  - Has emphasis on delving into details of various concepts and protocols:
    - Ethernet utilization derivation, TCP variants, ...
  - Has activities on using networking utilities and experimentation testbeds.
- All of which is appropriate for CS majors.

- Is such a course suitable for non-majors?

Networking course for non-majors

- Non-majors often get the same course as majors, for various reasons:
  - Faculty and students belief that non-majors should get the “same” course.
  - faculty disinterest in creating new material for a “service” course.

- However, non-majors typically need/seek some exposure to the interesting ideas in the area, so:
  - Delving into excruciating details is unlikely to be interesting.
  - Excess details and jargon are likely to be intimidating.

Desirable goals for a non-majors course

- Retain the core conceptual aspects of the major course.
- Reduce emphasis on content details that are “volatile” and unlikely to be used subsequently.

- Increase emphasis on transferable process skills, such as:
  - Developing technology/ solutions by systematically applying logical thinking.
  - Designing and evaluating multiple solutions to a given problem.

Our course learning objectives (Networking for non-majors)

- Get students to demonstrate conceptual understanding of Networking protocols.

- Demystify Networking technologies so that:
  - Students recognize that design choices for various technologies often stem from commonly known concepts in other real-world applications.
  - Students recognize that inventing technology is mostly a matter of systematically applying logical thinking towards a goal.

Our course approach

How do we:

- Reduce the intimidation effect of technical jargon without compromising conceptual understanding
- Increase the possibility of transfer

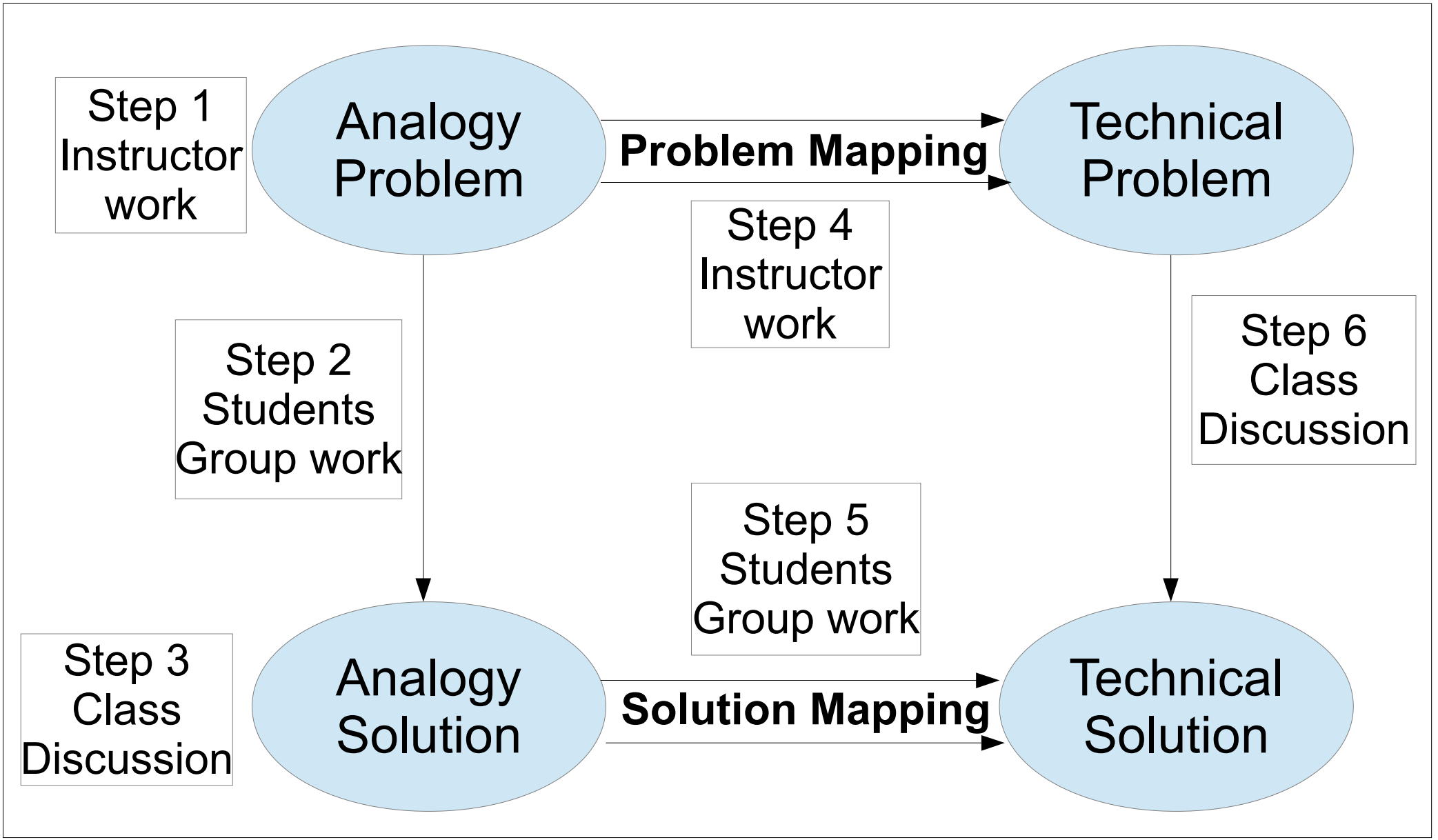
→ Analogical Problem Solving

How do we:

- Get students to recognize that inventing technology is mostly a matter of systematically applying logical thinking

→ Map their analogy solution to technical domain

Overview of Instructional Method



What was your solution for the CEO?

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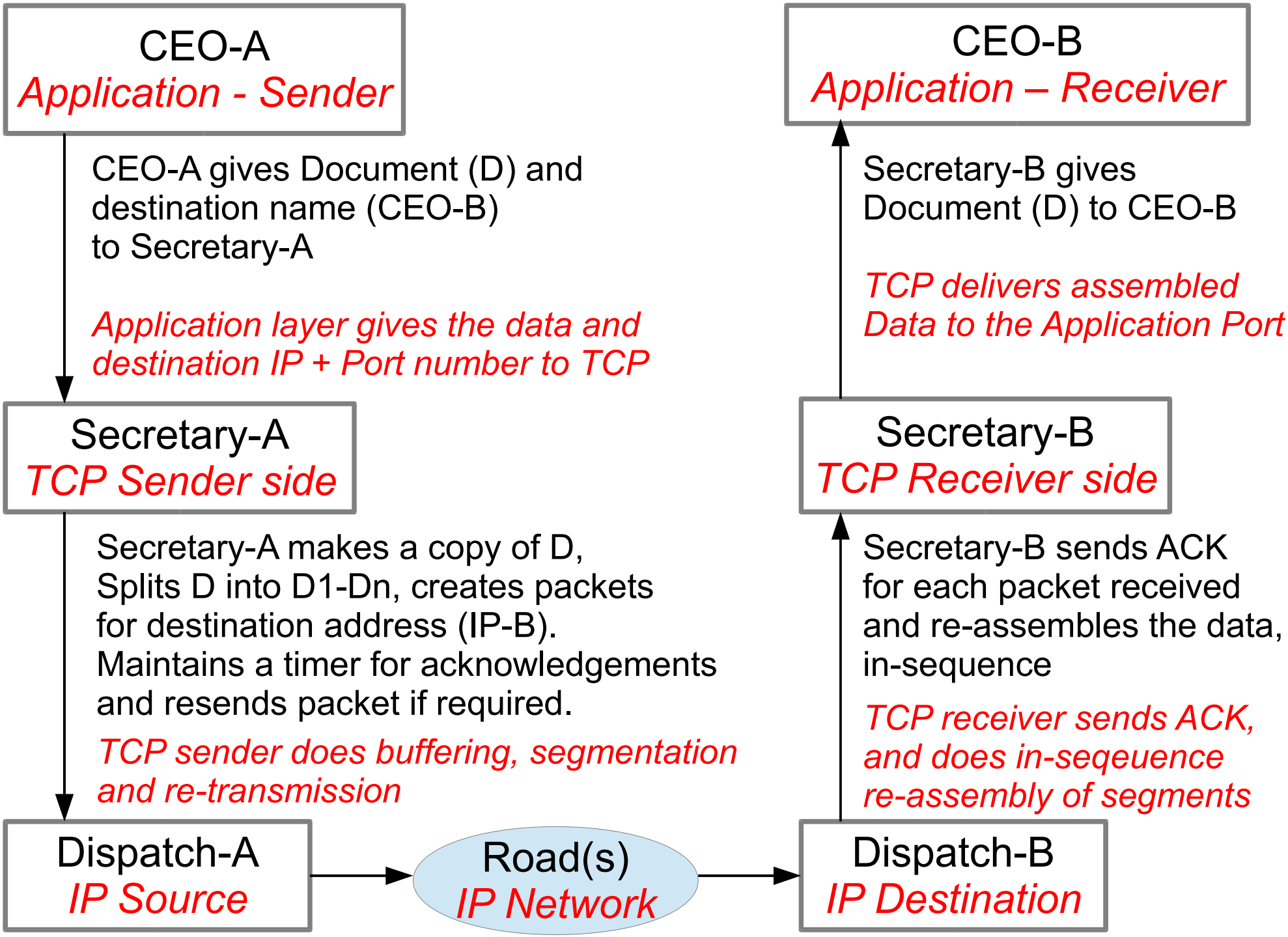

Unreliable messengers carry packets from A to B.

IP network provides 'best-effort' unreliable packet delivery

What is different in our Method?

Analogies have been long promoted as a cognitive tool to understand the properties of an unfamiliar idea using a familiar idea and are central to the development of scientific ideas [6].

The power of analogies lies not only in comparing the properties of two domains, but also in the development of new abstraction and mental models [4].

We take it a step further by:

Having students solve complex problems in the base domain (familiar real-life scenarios), and develop the necessary abstractions, which are then mapped to the target domain (networking).

Development of Instructional Material

- **Decide whether an analogy would be useful for a chosen topic**
  - to emphasize the broad applicability of the concept, or
  - to overcome the initial barrier of learning the details of a new technology.
- **Develop the analogy problem**
  - Consider real-world scenarios or fictitious situations using real-world elements that have an abstract structure similar to the Networking concept. Identify constraints to be imposed on the real-world scenario that can mimic the properties of the network.
- **Provide students with repeated exposure**
  - to real-life problems in which they have to design protocols for the given requirements and constraints.

Classroom Learning Environment

1. (5 minutes): Instructor poses question in analogy domain.
2. (20 minutes): Students do group problem-solving.
3. (20 minutes): Entire-class discussion.
   Each group presents their solution and class evaluates trade-offs and benefits between different solutions.
4. (5 minutes): Instructor maps the analogy problem to the technical problem.
5. (10 minutes): Students map their solution.
6. (30 minutes): Entire-class discussion.
   Details of technical solution are discussed.
7. (Subsequent 2-3 classes): Finer technical details.

Student Characteristics

Master's level programs across various domains, such as electronics, reliability, mechanical and chemical engineering.

Most of them did not have any prior undergraduate course in Networking.

Their objective in registering for this course was to get an exposure to communication networks and a working knowledge of various technologies such as TCP/IP, CDMA.

Evaluating effectiveness

- Offered as a semester-long course three times:
  - once each in 2009 (30 students), 2010 (62 students) and 2011 (28 students).
  - Just got around to writing the paper!

Evaluated if the primary course goals-

- demonstrate conceptual understanding and
- demystify technology -

have been met by the instructional method.

Testing conceptual understanding - 1

Comparison of four final exam questions of students from a traditional course and our students.

Final exam question	**Traditional group Mean (SD)** (N=63)	**Analogical problem-solving group Mean (SD)** (N=30)	**Difference significant?**
Problem 1	6.3 (3.6)	5.9 (4.4)	Not significant, p>0.05
Problem 2	3.5 (2.8)	5.0 (3.9)	Significant, p=0.04
Problem 3	4.7 (2.1)	5.0 (3.9)	Not significant, p>0.05
Problem 4	4.9 (3.8)	6.0 (4.4)	Not significant, p>0.05

Findings - 1

We analyzed students' performance on more than 20 test questions over the three years of our course

- Analogical problem-solving method is comparable or better than traditional methods in terms of students' performance on typical Networking questions,
  - despite the instructor not spending as much class time on typical treatment.
  - even though students spend significant class time discussing real life scenarios.

Testing conceptual understanding - 2

Applying concepts from problem solving in real life domain to new unseen topic in Networking domain

	Analogy problem (number of students)	**Networking problem (number of students)**	**Mapping done? (number students)**
A: Broad solution and details correct	13	11	11
B: Broad solution correct but a few details missing	13	12	7
C: Solution does not answer the question	3	6	0

Findings - 2

- students are able to productively abstract the relevant concepts from the analogy to solve a previously unseen technical problem
  - students who are successful in solving the technical problem, use mapping from the analogy

- using analogies instead of directly teaching in the technical domain is a feasible technique
  - students are able to solve a problem in a hitherto unknown technical topic by first solving the analogical real-life problem

Student perceptions of the course

- 45 minutes focus group interviews of 16 students

  "When I was solving a technical problem [in an exam], I only had to worry about a few minute technical details. The rest – the broad solution – was very clear because of the analogy."

  "Learning with analogies was a completely new way of thinking, this is thinking out of the box. … We are made to think about the actual problem underlying the scenario. Concept becomes easier to learn."

- Course evaluation data
  - 89.6, 84.2 and 87.8, for the three offerings respectively.
  - Comparable to the top course scores in our institution.

Instructor perceptions of the course

- a higher number of students were able to keep up with the technical discussion (in all topics).
- some students were able to come up with scenarios and explanations that indicate depth.
- students were able to replicate the technology evolution.

Challenges:

- after analogy solutions are discussed, some students tend to gloss over the technical details.
- ensure that the analogy is not extended to its breakdown point, which could lead to student misconceptions.

Take-away

To use Analogical-Problem-Solving in your course:

- Design the problems in an analogy domain that are familiar to students and also map well to the technical problem.
  - Use the analogy to draw students' attention to the core concepts versus distracting details.
- Let student-groups describe their solution during the class discussion. Let them see their analogy ideas appear in the technical domain.
  - Give students time to solve the analogy problem. Since the problem is in a familiar domain, students will eventually come up with a solution.

Questions?

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