Making a Case for Empathetic Cross-disciplinary Teaching of Networking

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ABSTRACT

We advocate an approach to teaching a graduate networking course that is doubly cross-disciplinary. First, it assumes a mixed class of students from EE/CS/IE, mathematics, physics, even economics. Second, it treats networking topics that are cross-disciplinary in nature. We also describe in detail such a course in action which focuses on the Internet. Our teaching experience so far is very favourable, and we attribute it to three good pedagogical principles, namely, empathetic teaching, modularity and storytelling.

1. INTRODUCTION

It is a truism that the typical EE/CS/IE[1] graduate programme - standard host of networking courses - admits students from various disciplines - electrical engineering, computer science, information engineering, mathematics, physics, etc. therefore courses therein face a basic problem. How do you make good sense to them all? Subsequently, there are two ways to teaching an EE/CS/IE graduate course, depending on whether diverse student background is taken into account. The pathetic way doesn't, and leaves it to students to make their own ends meet. They either make it or they don't. Fate has them, and survivors are likely students with the necessary background, or the precious few independent fast learners.

The empathetic way acknowledges diversity in student background, somehow. The benefits and disadvantages, over the pathetic approach, are quite obvious. More students survive, *ceteris paribus*. And for the same number of survivors, their backgrounds are more diverse. The downside is its serious demand on the teacher, who has to make an effort to address the diversity.

There are at least three approaches to empathetic teaching. The *GCD approach* bootstraps learning from common ground, beginning with basic and elementary materials - presumably mostly mathematical, some algorithmic, little electrical or physical. The *LCM approach* may be similar to pathetic teaching, baffling some most of the time but none all of the time, but makes sure students of different disciplines find their ways out with sufficient options, especially in course works and examinations. The popular seminar course model is subsumed here. The *cross-disciplinary networking("CDN") approach* is a kind of holy grail in empathetic teaching. Bridges are built for students of different disciplines to cross, meet in , and learn concepts that benefit from a cross-disciplinary treatment. There are two further subdivisions. The *weak CDN approach* invests in $O(k^2)$ bridges among k disciplines, suitable perhaps for an expansive treatment that surveys cross fertilizations. The *strong CDN approach* invests in $O(k)$ bridges that connect the disciplines to a new propped ground for a more focal treatment of some topic in concern.

This position paper advocates this *strong CDN approach* to empathetic teaching of networking on graduate level, and describes the design, content, and delivery of such a course in action.

2. THE BIG PICTURE

A graduate networking course may afford to pass over *archaeology* of the foundation, details of protocol stack and the like. Any school qualified to offer such a course must already have some basic networking course there already digging, a default home court of most CS/IE students and some EE students.

Counting on, other home courts brought to class may include at least some of the following:

- Electrical engineering, with students ready with linear systems and control;
- Mathematics, with students ready with system theory and discrete mathematics;
- Physics, with students ready with statistical physics;

[1]Information engineering departments are common in China, including Hong Kong, with a focus in communications and information processing.

- Economics, with students ready with microeconomics and statistics.

A *strong CDN approach* shall systematically build at least one bridge per home court towards the propped ground. On a bridge head, per CS/IE say, the home students may have a relatively easier time reviewing while the road students learn a careful selection of concepts, such as packet switching, network access, protocol, layering, routing, etc. It is important that the treatment is elementary, from first principles, for the sake of road students. Bridge by bridge, a set of concepts are collected from different home courts towards as well as prodding a new ground.

The topic for which the new prodded ground is built determines what concepts are selected instrumentally from the various homes in the first place. *Massive Graphs and Networking ("MGN")*[2], a graduate networking course offered three times in the past eight years in IE Department of The Chinese University of Hong Kong (CUHK), puts the Internet there[3]. The advantage of treating the Internet on a purpose-built cross-disciplinary common ground is clear. The Internet as an expansive research field continue to defy academic disciplinary restrictions. We may even say that many knotty problems of the current Internet arise from disciplinary tunnel vision, mostly of EE/CS/IE kind. That a cross-disciplinary treatment is long due is a common take; we just do not know how to do it properly. A graduate level course that rounds up concepts *as well as students* from across relevant disciplines may be a small but significant step towards it.

In the following, we give a detail description of the MGN course.

3. A BRIDGE AT A TIME, A STORY AT A TIME

Modularity is a great guiding principle. A *strong CDN approach* delivers its content over bridges and prodded ground, both being modules that effect good pedagogy in a cross-disciplinary setting. The MGN course modularizes the content further into *stories*. Loosely speaking, a story is a self-contained narrative, organized around how original ideas developed one after another wherever possible, with some clear theme that takes one or two standard lectures. The MGN course tells relatively well defined bridge-building stories before moving on to more open-ended stories on the prodded ground, about Internet issues, treated in their original cross-disciplinary richness.

[2]Homepage of an early offering is http://personal.ie.cuhk.edu.hk/~wyng/mgn/

[3]The Internet is an obvious choice though not necessarily the only possible one. Debating what networking topic or focus may suit better is worthwhile, but we shall leave it for the time being, perhaps until the next SIGCOMM Education Workshop.

Currently there are altogether twelve stories in the MGN course. The following are bridge-building stories:

1. **The Internet story** is a primer of the Internet as an engineering system, a network of networks, told in the manner of an intellectual history of ideas and architectural concepts in computer networking, the essential ones being packet switching, network access, protocol, layering, routing, etc.
2. **Google story** describes the basic PageRank algorithm, exemplary of link analysis as a powerful approach to analyzing large graphs such as the Internet.
3. **Organic web story** describes local patterns in a directed graph, such as hubs, authorities and clusters, and node and link statistical measures. The HITS algorithm is then described, leading on to general problems of mining the ever-changing Internet.
4. **Power law story** tells the story of how (alleged) power laws excite, inspire as well as fail expectations. This leads to network measurement and Internet mapping.
5. **Small world story** describes the fascinating small world as an emergence phenomenon and how it makes network routing scalable. This leads to routing and search problems on the Internet.
6. **Random graph story** is a primer of random graph theory that illustrates the use of probability and statistical physics in analyzing basic random graphs, including the Erdos-Renyi model and the degree distribution model. Classical results of epidemic spreading and percolation are discussed, and their potential use in modeling Internet phenomena.
7. **Network crowd story** is a primer of transport economics of source routing, introducing the concepts of Nash equilibrium, social cost, coordination and mechanism design.

Then the class is ready for the following open-ended stories:

1. **Network market story** described congestion collapse and how Van Jacobson saved the world, resource economics of network access, the smart market model, the Kelly model of resource allocation, and leads on to the interplay between Internet congestion, traffic types, network and overlay routing.
2. **QoS story** looks at the Internet from the performance perspective and portrays the (lack of) progress in QoS mechanisms since commercialization of the Internet.

This story is a fitting lesson for a cross-disciplinary class to see how unwieldy Internet has become and how entrenched the current Internet standards are. This story leads to discussion of architectural issues and principles.

3. **Internetworking business story** is a primer of the evolving industrial organization of network service providers, highlighting cooperation on technical level for resource sharing and competition in both retail and wholesale markets. This story leads to the general problem of network formation and strategic interaction among stakeholders.

4. **Net neutrality story** tracks the open debate among (or between?) service and content providers that is a constant jumble of technical, economic and political considerations. Network effect is a central concept to be treated here. Cloud computing is an emerging new kid on the block. This story leads to discussion of Internet regulation and policy analysis.

5. **Social networking story** tracks the rapidly evolving social Internet which may or may not cause serious impact on the Internet infrastructure, but certainly accentuates security concern. The full picture is another jumble, this time entangling social, political, even ideological issues. This story is another fitting lesson for a cross-disciplinary class to ponder on the appearance of perhaps another discipline, and yet another bridge.

4. DISCUSSION

Many education psychologists advocate storytelling[4] for teaching and learning. The story format, with an intentional flow and some sort of plot, helps motivate students, which is important for encouraging them to cross their bridges. In fact, the dramatic development of Internet as a history of ideas, an engineering system and a platform of platforms is ready with many interesting stories to be told. Our teaching experience so far is very favourable, and we attribute it to the three principles of empathetic teaching, modularity, and storytelling.

Compared with a seminar course around a selection of papers, teaching the MGN course requires more careful organization. Compared with a more conventional topical graduate course, it contains self-contained modules which are related by purpose much more than by requisite. It empathizes with the varied needs of a class of students from different disciplines. When such a class has crossed all bridges and gathered at the prodded ground, everybody is ready for a cross-disciplinary look at the Internet. Indeed the rich picture of Internet may now be seen clearer with less disciplinary restriction.

Discussion of course design is not complete without a word on assignment and assessment. We use a combination of reaction papers and a final examination. Two reaction papers test appreciation and analysis, with one on a bridge-building story and one on an open-ended story. The final examination test problem solving with more standard questions.

5. CONCLUSION

As the typical graduate course in networking is open to students from multiple disciplines, we advocate the *strong CDN approach* for content delivery to as well as networking of students from different disciplines. Modularity and storytelling are useful empathetic principles. Our MGN course tells stories that bring students from their home courts to the Internet, a cross-disciplinary topic in itself that defies academic disciplinary restrictions. It is also obvious that the *strong CDN approach* is relevant to teaching any class with students from different disciplines, for whom empathetic teaching and networking would be greatly appreciated.

[4]Certainly we may argue forever what is and is not a story. Let us be a bit casual here and assume we have sufficient agreement on what it is for the purpose of our discussion.