Teaching Statement

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I believe the ability to question and understand the fundamental concepts and the key challenges in each field is of utmost importance for an independent researcher, and developing this ability begins in the classroom. I will overview the new courses I plan to offer to prepare the students for their careers. Then I will elaborate my teaching approach, followed by the lessons I have learnt from my experiences in teaching and mentorship.

1 Teaching Plans

Over the past 50 years, there have been rapid changes in networking capabilities, going from slow networks with ample slack in the software to process the packets, all the way to fast networks where the network bandwidth is outpacing the software capability. To cope with this evolution, new techniques were developed to improve software efficiency, such as bypassing the Operating System (OS), and offloading some of the functionalities to customized hardware, which in turn increase the development complexity. However, most network courses in Computer Science (CS) merely brush upon the hardware and operating system elements and focus on the IP layer and above, without covering the use of hardware accelerators. On the other hand, most communication courses in Electrical Engineering (EE) focus mostly on the physical layer, such as communication over copper, fiber, and wireless, without covering much from the higher layers, or how the packets traverse the hardware components and get delivered to the software.

Following these trends, I believe that students can benefit from new courses that cover the architecture of networking hardware, and also bridge the gap between the fields of networking, hardware design, and communications. I believe more holistic courses will open up the potential for co-optimization among network layers, which can further address the increasing gap between network bandwidth and compute capability. To this end, I am considering two new courses to offer, for students in both EE and CS departments:

An undergraduate networking course with focus on the life of a packet before it reaches the software: Due to the compute capability gap, there are methods to bypass the OS kernel, such as DPDK and XDP [1], which benefit from hardware customization such as DDIO [2], and support from the Network Interface Card (NIC), such as XDP hardware offload in Mellanox cards, or eBPF engines in Netronome cards. I will elaborate on how digital data is processed with hardware accelerators within NICs, then traverses the PCIe bus to the main processor, how it arrives in processor cache or system memory, and how it gets to the software, with or without kernel intervention. Then I would introduce the students to examples of these technologies already running in production, and define a course project to use them as a cloud service. This course provides students with an understanding of the underlying system, enabling them to develop efficient programs that have become a necessity for today's networks.

A graduate networking course with focus on the evolution of network infrastructure: The network infrastructure has dramatically changed over the years, from changes in the link technology to changes of roles of components within a network. For example, NVIDIA NVLink is targeted for High-Performance Computing (HPC) as a new physical and data-link layer design, and new link technologies such as Silicon Photonics are also on the horizon. Another example is use of network middleboxes in datacenters to protect against network attacks and to load-balance the incoming requests among the servers. There is also a rise in use of programmable network switches to use the network resources more efficiently. I will describe trends in network links, and then go one level higher and introduce programmable switches and NICs that use P4 [3] language, as well as high-performance network middleboxes that use programmable hardware (FPGAs). I will use the Shire framework, that I developed for FPGA-based middleboxes, to help the students conceptualize how packets traverse through the hardware, and for the final project, build a miniature network infrastructure. This course provides a better understanding of the network infrastructure capabilities, as well as a fertile ground for research on co-optimization within lower network layers.

Furthermore, based on my background in computer architecture, I can teach both undergraduate and graduate computer architecture courses. In the undergraduate course, I will add more introduction to new open-source processors such as RISC-V, an open RISC instruction set architecture and its extensions, which is becoming widely adopted in embedded applications. For the graduate course, I will add more introduction to the Network-on-Chip and Network-in-Package, as multi-core processors have become widespread, and use of multiple dies per package is increasingly becoming more popular in the ARM processors ecosystem, and will even be adopted by Intel soon.

2 Teaching Approach and Experience

I truly cherish and enjoy teaching concepts for which I can give a complete picture of what a system is comprised of, and why it is designed as such. I have seen over and over that students learn a subject best if they can follow the stream of reasoning behind the concept, and why something is done in a specific way, as opposed to only knowing what solution is being used. For example, many students learn only the theory of a concept without learning any of its applications, and consequently they quickly begin to forget the concepts. I believe that the first step in teaching

[1] DPDK: Data Plane Development Kit provided by Intel, XDP: eXpress Data Path based on Extended Berkeley Packet Filter (eBFP)

[2] DDIO: Intel Data Direct I/O Technology to transfer network packets directly into processor cache

[3] Programming Protocol-independent Packet Processors, programming language for supported network devices

should be for the students to apply the theories and see their outcomes, preferably through visual results. However, visual results are still not sufficient, **as students usually learn to only operate within the framework that was designed for the homework**, especially for undergraduate courses. My teaching approach is to walk the students through the challenges that led to a design at a high level of abstraction, which from my experience considerably helps the student to better understand the concepts and be confident to use them outside the classroom. One of the main obstacles in achieving the goal of comprehensive understanding is the complexity of current systems, but I strongly believe that use of networking capabilities on affordable embedded devices can play a pivotal role in depicting a comprehensive image; instead of only seeing a few LEDs change state, students can transmit actual data packets between the host and the embedded device.

During my undergraduate studies at Sharif University of Technology, Verilog language for hardware programming was taught as an independent side session for the "Logic Circuits and Digital Systems" course, which was required for around 200 undergraduate student per year. I had found better teaching methodologies for Verilog, and **took it upon myself to revise the syllabus**. I became the instructor for every faculty member offering the course for three consecutive semesters, to continuously update and enhance the syllabus, and before graduation, conveyed the syllabus to the next teaching assistants. I also held discussion and recitation sessions for several other courses, adding up to a total of 10 classes during my undergraduate studies, which significantly helped me with my teaching and class management skills. Because of my fascination with visual observation of results, I also became a laboratory teaching assistant for nine courses, where I learnt the value of clarifying the big picture behind the design of the experiments of the day. This led me to update the lab instructions for *Structure of Computer and Microprocessors Lab* course, become a member of the design team for *Embedded Systems Lab* course, and also lead the effort in overhauling the *Microprocessor Lab*.

During my graduate studies at UC San Diego, I helped with designing a new processor for an undergraduate computer architecture course, and even though I was not the TA for that course, I attended some of the TA office hours to see how the students are using this processor, and help them with their questions. Later on, I became the TA for the graduate computer architecture course, which was held for 140 registered students with only two TAs. I tried to be on top of online questions at Piazza, and the main lesson that I learnt during the office hours was to ask the students to start writing the problem and their initial thoughts on the board, and with a little guidance they could understand the contents much more concretely. These efforts helped the students and the overall feedback from them was welcoming, with comments such as *"[Moein] was incredibly active on course forum, and responded quickly and clearly to questions"* or *"Very responsive, made an effort to explain concepts and clarify doubts"*.

I was also a guest lecturer for the undergraduate networking course at UC San Diego, teaching the session on the role of hardware in networking. While preparing for that session, I was contemplating how to best introduce a fundamental concept regarding error detection, and this made me realize how undergraduate courses can provide a unique opportunity to review and better understand the concepts that we take for granted. Moreover, I was a teacher at a middle school for a year, teaching algorithms and web programming, where I was impressed by their fascination and enthusiasm—maybe even more than most university students I have interacted with—–in finding faster solutions or expressing themselves through web interfaces. I aim to bring out such enthusiasm in university students by teaching in a holistic manner and making them feel confident in the course material.

3 Advising and Mentorship Experience

During my graduate studies, and later my postdoc time, I was more interested in mentoring and advising. During this time, I helped and mentored around 20 individuals. Through these one-on-one sessions, I would first gather a deep understanding of their interests and goals, and then check up on those over time. In my capacity, I give them the best resources and advice to let them lead and achieve their goals. This approach allowed me to advise in a wide variety of areas, ranging from helping a friend of a friend who was struggling at work, to an undergraduate bio-engineering student who was interested in learning more about wireless communication. One of the mentoring experiences that stands out for me is a Ph.D. student, a few years my junior, who was really struggling and even considered leaving school. I tried to point out their achievements, and what most students go through in graduate school. Later on, they told me that they thought of me as a role model. I was delighted to see them graduate and land a job in a prominent scientific institute as a researcher. Afterwards, I stay in touch with those individuals, for example, I have mentored one of the students from the junior high school class that I taught, **amounting to almost a decade**, and seeing them grow both in personality and knowledge has been elating.

I have also mentored the junior students in our group on how to perform proper research, which led to several paper collaborations. Especially, I asked my postdoc mentor to provide me with the opportunity to **mentor one of her Ph.D. students**. During this period, I became confident that not only did I enjoy teaching in class, but I truly relish flourishing students' ideas, helping them avoid dead-ends and unfruitful directions that I faced before, and **to prepare the environment for them—both technically and emotionally—to be able to do their best**. Aaron, my Ph.D. advisor, once said that one of his joys of becoming a faculty member is to see the growth of a student, and how they improve in their work and method of thinking. Such joy was indeed my experience with this Ph.D. student, and I look forward to having the same experience with many more students to come.