

Reconfigurable context reactive blended networking and communication courses

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ACM Reference Format:

Ciarán Mc Goldrick and Meriel Huggard. 2020. Reconfigurable context reactive blended networking and communication courses . In *Teaching and Learning Computer Networking During the Pandemic and Beyond, Online Networking Education Community Discussion, August 05–06, 2020, Online*. ACM, New York, NY, USA, 4 pages. <https://doi.org/10.1145/nnnnnnn.nnnnnnn>

1 INTRODUCTION

This white paper briefly documents the authors' experiences in developing and delivering graduate level educational experiences and outcomes in courses substantially built around computer networking content and principles - through traditional academic, blended and wholly online delivery and engagement modalities. The approach, strategies and content have been developed, delivered and refined over multiple presentations, and have been validated with class sizes of over 100 full-time students per presentation.

Efficacious graduate education is, of necessity, both individual and collective in scope and nature. A key, perhaps indispensable, component of the nurturing and development of many core graduate attributes is the nature and quality of the mentor/apprentice learning, experience, and interactions that are both mandated and organically fostered during this time. Encapsulating and validating these facets in blended learning or wholly online settings is at the core of this discussion paper.

The approach, concepts and principles also translate readily to senior undergraduate settings [1] [4], and were successfully employed in a pandemic-inspired Innovative Networking solutions challenge that ran in March and April 2020.

2 STUDENT COHORTS

The international graduate cohort taking the Scalable computing course are highly diverse in terms of their educational background and academic profile. All will have come to our University to pursue one year full-time taught MSc specialisms in Future Networked Systems, Data Science and Intelligent Systems. The cohort is supplemented by a small number of first year research PhD students.

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SIGCOMM Edu '20, August 05–06, 2020, Online

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ACM ISBN 978-x-xxxx-xxxx-x/YY/MM... \$15.00
<https://doi.org/10.1145/nnnnnnn.nnnnnnn>

The nature of the student cohort lends itself to the creation of innovative and challenging practical tasks in the converged networking and intelligent systems spaces.

The undergraduate cohort are drawn from the third year of a five year integrated engineering program, where students graduate with a masters level qualification. A notable feature of this cohort is that almost half the class are International students who have just come to our University in third year as part of a joint degree programme offering.

3 INSTRUCTIONAL STRATEGY

The instructional strategy employed has many common elements for both courses, and their respective student cohorts. A unifying concept is introduced at the outset of each module, and the activities are structured and scheduled to appropriately scaffold and support student progression toward the associated learning outcomes. The specificity of the initial minor, individual, goal-oriented, skill building practical activities is supplanted and evolved towards a more minimal, problem-domain oriented, group activity. In this latter stage the students seek to identify and leverage the "best of breed" elements of their early individual works, and converge these towards effective solutions to networking aspects of domain problems of their choosing.

3.1 Graduate Course

Scalable Computing, in the mainstream Computer Science psyche, is strongly (and narrowly) associated with Cloud Computing approaches and concepts. In practice Scalable Computing can, and does, mean much more than this. For the course in question, delivery begins with a focus on the the purpose, use of, and constraints associated with Internet of Things (IoT) devices. IoT is chosen as the underpinning integrator paradigm for the course, as it enables both academic and practical real world exploration of the principles, concepts, realisations and deployments of many Scalable Computing concepts covered in the course.

Scalability in terms of size, density, power, efficiency, discovery, collaboration, networking, communication, security, constraints, etc. are all researched, evaluated and assessed through flip classroom, shared whiteboard, online forum and remote teaching and learning modalities. Drilling into these, and having regard for the cohort and their interests, leads naturally to the inclusion of processing capabilities and associated scalabilities and efficiencies (e.g. local and networked CPU and GPU resource scalability and sharing, and thence to Cloud principles, concepts and actualities). Thereafter the course extends towards extreme scalability through academic

and conceptual consideration of nano and quantum networking and computing concepts and facets.

This white paper focuses on the practical aspects of the course that are of relevance for the Future Networking and Intelligent Systems specialism of the graduate program. In particular, focus will be placed on (largely) infrastructureless networks, and resultant concepts, as this forms a nexus for each specialism cohort to engage with and through.

By way of illustrative example, tasks in the past two years have included distributed hash cracking, distributed captcha solving, and highly distributed and scalable IoT modelling and simulation. These tasks build in scale, complexity and resource requirements as the course progresses and have their genesis and underpinning in the graduate course title: Scalable Computing.

3.2 Undergraduate Course

The undergraduate course content will be more familiar to the reader as it is strongly aligned with the standard computer networking texts and syllabus e.g. akin to Networking 101 and the texts of Peterson and Davie [7] or Kurose and Ross [5].

The initial practical activity builds on the standard http style socket programming task whereby each student focused on incrementally designing and building their own decentralised, distributed data fabric provider for intermittent communication, such as could be used to interconnect fragmented silos of data, or link together unpredictable communication devices.

Examples of such scenarios include intermittently connected Internet of Things devices, vehicular networking scenarios, underwater communications paradigms, space communications, etc.

The students' attention is drawn to a number of open source platforms built with similar goals and principles, and they can use these to inform their design. However they are instructed not to directly use their code, libraries or any of their toolsets.

There are three, co-dependent projects in the undergraduate networking course : Project 0 (the initial research, specification and definition of scenario, approach, principles and protocol); Project 1 (implementing a simple, reliable messaging infrastructure that implements the core of their Project 0 design) and Project 2 (a group project where students will take the best of breed concepts and implementations from each group member, and implement and demonstrate their functional solution to a broad domain challenge).

In the 2020 module delivery, and in light of the evolving pandemic, the exemplar specified for the students to focus on for targeting their decentralised, distributed data fabric provider design was that of the looming global COVID-19 pandemic.

4 SAMPLE TASKS

By way of illustration of the differing project tasks and goals, and associated scaffolding provided, the descriptors for undergraduate Project 0 is included below, followed by the group task descriptors for both the group graduate and (pandemic) group undergraduate project tasks.

4.1 Undergraduate Project 0 task guidance

For Project 0 students were required to produce a (maximum 5 page, 11pt font, including diagrams as appropriate) design and

specification document for their proposed data fabric and elements. They were required to address the following aspects, in appropriate detail, in their document.

- i) Preferred Use Case - Identify the key features, requirements and constraints of your preferred use case (as relevant to your planned design and implementation). Demonstrate that you have appropriately considered other use cases.
- ii) Protocol Overview - Describe your design at a very high level. How do systems and your nodes/devices communicate with each other in and through your fabric provider?
- iii) Communication Model - Develop a communication model for your system. Your communication design should be sufficient for your proposal, and proportionate to the length, duration and scale of this course. Your design should include adequate and sufficient identification of and consideration of security aspects.
- iv) Module Descriptions - This should not include individual classes; instead, illustrate anticipated design interactions and trust boundaries, network relationships, and so on. Also, tell us which module is responsible for which security goals, which functionality goals, etc. and provide motivations for the tradeoffs that you make.
- v) Summary of Algorithms - This section should discuss any communications, functionality and security critical algorithms that your system will use. It should provide an overview of the algorithm and a description of the operational guarantees that you hope to achieve by using the algorithm or approach. Use pseudo code at your discretion, but real C/Python/Go/Java code is inappropriate. If you plan to make use of any custom libraries, systems, codebases, cryptographic protocols, etc you should identify them, motivate and justify their use, and include a sufficiently detailed discussion in this section. If you plan to use of off-the-shelf networking, communication or crypto fabrics or implementations, explain how you plan to make use of the functionalities those platforms and systems provide.
- vi) Software Development Practices - Explain how you plan to apply good, efficient, best-of-breed approaches and security relevant programming practices to your design. (Eg: Defensive programming, least privileges, testing, and other relevant concepts). Please note this is not a software or software engineering project – please make sure you keep your focus on the networking and communication concepts and aspects. This software section is intended to provide confidence to a reader that you intend to design and implement in a professional and convincing fashion.

4.2 Graduate Project 2 group task guidance - remote version

This project is titled: Scalable Communication on an Internet of Things scale. The purpose of this project is to implement, validate and demonstrate a simple scalable communications protocol that employs Peer to Peer modalities of the type that might be found in (a) Unmanned Aerial Vehicles (Drones), (b) Vehicular and (c) Body Area Networking communication scenarios. You will be asked to

explain and justify how your chosen implementation is relevant to, and incorporates features intended for one of (a) - (c) above.

- i) Your implementation must be scalably deployed for use and I have provided you with a link to a sample skeleton AWS implementation that uses AWS and Lambda to achieve the scalable internet deployed elements. Please note that you will still have to implement your sensor models/characteristics and take care of connecting and communicating with and between no less than 4 separate and distinct machines/AWS instances simultaneously.
- ii) Each machine/instance must implement no less than 10 distinct local entities ((c) Body Area Networks (BAN) sensors/devices) that represent relevant and sufficiently accurate scalable implementations of relevant behaviours for Body Area Networking scenarios.
- iii) Please note that your system should demonstrate some capacity for interoperability with other classes of device, for example, (a) unmanned aerial vehicles (drones) or (b) vehicular networking communications. You will be asked to explain how and where in your design you anticipated this.
- iv) You should build a simple justifiable model for each device that appropriately represents/emulates key properties and behaviours of each device class. These do not need to be perfect but your group should have sufficient justifiable belief and conviction in them to make a credible, informed defence of your design decisions and implementations at demonstration, presentation and in interview. These will be deployed/associated with the relevant Lambda function in your deployments. These may be simulated, although you are welcome to, and encouraged to, interface instances to any suitable real hardware that you might have available. We can make some Raspberry Pi 4's available if you wish to configure them to generate suitable live data streams that you intend to interconnect with your Cloudformation template.
- v) Your specific, assessable implementation should provide for, and clearly demonstrate, simulated mobility appropriate to the relevant device class assigned to your group. You may use any appropriate mobility, discovery and routing approach/model(s) as your group agree suitable for the task. These design and implementation decisions should be both local and specific to your group. Please document your choices and rationales as part of a final design document will be required as a submission.
- vi) You should provide for dynamic/unanticipated unavailability of devices within your system and protocol design as appropriate e.g. nodes moving out of comms range, nodes going to sleep, nodes dying.
- vii) You should implement no less than the prescribed number and types of devices and entities per device. You are free to implement as many more as you see fit.
- viii) You must use multiple devices and/or instances in your solution to the task.
- ix) Your approach and solution should be both carefully considered and maximally scalable in design and implementation. These will be key assessment aspects of your solution.
- x) Please use the discussion board - it can be exceptionally useful for all in tasks such as these.

4.3 Undergraduate Project 2 group pandemic task guidance

For the undergraduate course, the task was described as follows:

COVID-19 is materially changing everything you do on a daily basis. It is becoming increasingly endemic in many of the first world countries, and is expected to rapidly spread to second and third world countries. Different countries, and continents, have different levels of preparedness – infrastructurally, politically, medically, etc.

For project 2 take an aspect of the COVID-19 pandemic and propose a well-considered solution to a problem of your choice that can make a meaningful difference to the global fight against the pandemic.

Your solution should demonstrably draw on your synthesised Project 1 experience and knowledge – i.e. it must have and be demonstrably related to networking/communications and the course. Specifically you should

- i) Form a brief (1 page max) summary of the various strengths and beneficial features of your collective Project 1 knowledge and experience – effectively a synopsis/aggregation of your lessons learned and expert knowledge that you have all discussed and agreed on at the outset
- ii) Identify the aspect or facet of the situation and its needs and requirements that you plan to target to advance capacity in
- iii) Identify the networking/communication aspects of your planned approach and solution
- iv) Identify and other requisite knowledge and/or skills necessary to realise your solution/approach
- v) Agree on the solution, or subset thereof, that you can credibly implement in 10-14 days
- vi) Plan your test cases and validations for your implementation
- vii) Plan the activity in a demonstrably fair balanced fashion and agree distributed responsibilities across the group
- viii) Tightly and collaboratively manage, agree and execute the implementation
- ix) Validate and execute your test cases and implementation
- x) Reflect on and comment on the value and potential importance of your solution and implementation
- xi) INDIVIDUALLY: Include a paragraph on your individual group and peer learning experiences on this task (approx. 10 lines each)
- xii) Any other observations or content not otherwise covered

5 REFLECTION

By its nature, the online environment is commonly perceived as placing a “fourth wall” or barrier between the academic and their students. It was observed by the authors that this can dilute and compromise a student’s sense of professional, ethical and collegiate responsibility and engagement. Future online presentations of the courses described above will place a stronger focus on the development and refinement of students’ professional and ethical mindsets; for example, in relation to individual online assessments. During timed tests students who are performance oriented [2] can be tempted to exploit the easy availability of collaborative chat groups and internet search engines. While collaborative and cooperative learning [3] are to be encouraged during group activities, it is essential that students appreciate that such behaviours are

unacceptable for individual online assessment activities. The online learning and assessment strategies and modalities must be designed to proactively anticipate, mitigate and positively influence student attitudes and behaviours.

Plagiarism and similarity detection tools [6] are actively used to encourage students to develop their writing and coding skills and to learn the importance of individual “expression” when completing reports and assignments. In early assignments students are allowed multiple submissions before the deadline and can see the similarity report for each of these submissions. While it should be noted that this does not fully mitigate against paraphrasing or code similarity, it has been found to be an effective way of discouraging overt plagiarism. For later assignments the number of submissions permitted is reduced and for the final assignment a maximum of three submission attempts is permitted. Importantly, the assignments necessitate strong judgement, discernment and discrimination in relation to materials found online.

Existing group work activities translate readily to the online environment. In general, the student cohorts were experienced in the use of online meeting and chat tools for the conduct of group meetings and activities. Group meetings involving the instructor were longer in duration than their in-person counterparts, particularly where the instructor was required to deal with issues relating to the effective operation of the group and the management of their collective effort. The instructor noted that meetings where all team members used video were more effective and, for future course presentations, video will be required for online group meetings. It was observed that the fluidity and frequency of apposite technical discussions between the students and the instructor was significantly

impeded in the online setting. In future online course presentations the instructor will be more attuned to leveraging such teachable moments as they arise.

6 CONCLUSION

This white paper succinctly describes undergraduate and graduate courses that have been designed and structured for remote delivery. The practical tasks and activities can, and have, been shaped and purposed to enhance the students capabilities to apply and employ their knowledge and understanding of networking principles and concepts in the furtherance of societal good.

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