A board game for teaching internet engineering

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Abstract

This paper describes elements in the development of a board game for teaching Internet peering as part of an Internet engineering class.

Keywords: Internet engineering, Internet peering, team game.

1 Introduction

"Theory without Practice is Idle, Practice without Theory is Blind" Qigong teaching cited in Guba (2002)

Undertaking large group projects with real-world elements are seen as highly effective means to integrate student knowledge and practice within undergraduate degree classes and has been developed within various areas in Computer Science, such as computer games development, networking and IT (Joyce, Knox, Dann & Naps 2004). In this paper we discuss the development of a network engineering project for students majoring in Internet Computing as part of a Bachelor in Information Technology (BIT). The project enables the students to practice key aspects of their major. Specifically the project exposes students to project development based on Internet architecture and business through an analysis of Internet peering through lectures and a group game.

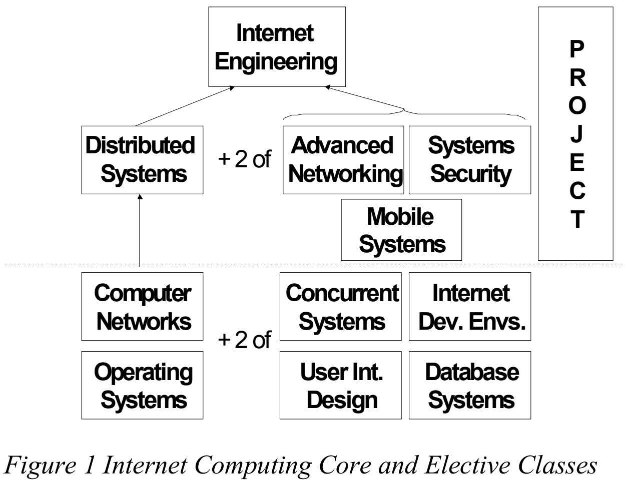

Figure 1 Internet Computing Core and Elective Classes

The BIT is a four-year degree with four possible specialisations: Computer System Engineering; Information Systems; Internet Computing; and, Software Engineering. Internet Computing focuses upon the emergence of network systems as an area of specialisation. The core and elective classes comprising the major are identified in Figure 1 The degree also includes classes covering core subjects such as project management, ethical and legal issues and software engineering. In the fourth year, in addition to elective classes, all students majoring in Internet Computing must complete a substantial individual project, a Distributed System and an Internet Engineering class.

The peering game is one project of two undertaken by students in the Internet Engineering class. The game exposes students to current technical, business and political issues in the Internet. The game is introduced to the students through a short series of lectures, which in this first running of the class came from leading local industry figures. The students are then split into teams and play through the life cycle of an Internet Service Provider (ISP) over a period of two game years.

We use the peering game to support experiential learning where "learning is seen as the process whereby knowledge is created through the transformation of experience" (Kolb 1984). We used the "ripples on a pond" model (Race 2001) to structure our use of the game. In this model learners are motivated by wanting to participate in doing, digesting what they have done and both generating and receiving feedback upon their reflections. Unlike Kolb's initial model these activities do not form a cycle because learners may be in any of these phases at one time and these phases actually reinforce each other.

The peering game itself is used to motivate student engagement (wanting) and to allow them to experiment with peering (doing). The game is played over multiple sessions allowing players to digest what has happened and to both generate and receive feedback that influences subsequent game play. When the game has finished formal assessment is used to support further digesting and feedback phases.

This paper focuses on the development of the peering game and the students' experiences. Section 2 provides a background to the peering game, section 3 looks at the peering game itself, section 4 discusses the students' experiences within the game, section 5 discusses proposed game improvements and section 6 discusses related work.

2 Background to the Peering Game

What is Internet peering? What is the peering game?

Internet peering is highlighted through Figures 2 and 3, taken from two papers by Bill Norton. Peering refers to the interconnection of Teir 1 and 2 Internet Service Providers directly at a neutral Internet Exchange (IX) point, rather than purchasing transit connectivity from a telecommunications provider or from the dominant Teir 1 ISP. Typically the cost of connectivity from a telecommunication provider or Teir 1 ISP is costly and if a Teir 2 ISP can build their infrastructure to an IX they are able to peer with other Teir 2 ISPs for a fraction of the cost. The benefits of peering are (i) cost reduction (ii) optimisation of traffic (typically minimising latency). For example in the New Zealand scenario the two main players in telecommunications connectivity do not peer locally and so ISPs dependent on these providers for connectivity may find that their local Internet traffic is routed through the USA, adding many 100's of milliseconds to the end-to-end delay.

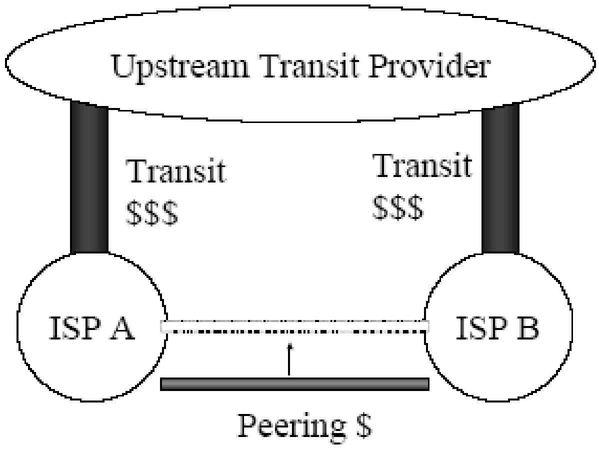

Figure 2 Peering or Transit? from Norton, 2000

The peering game was developed by Bill Norton of Equinix. Equinix is a Internet peering and data centre service provider, more details about Equinix can be viewed on their website at <http://www.equinix.com>. The game is a demonstration of the benefits of peering in action and a chance for peering coordinators to gain negotiation skills (Norton). It is played typically at conferences and workshops dealing in the Internet industry. The game can be played with up to four teams of ISPs; for our game this is ideally played by teams consist of three or four people. The game also has potential for the telecommunication providers to also be played by similar sized teams within the game architecture. This could be envisaged as an interesting example of market dominance at play, discussed later.

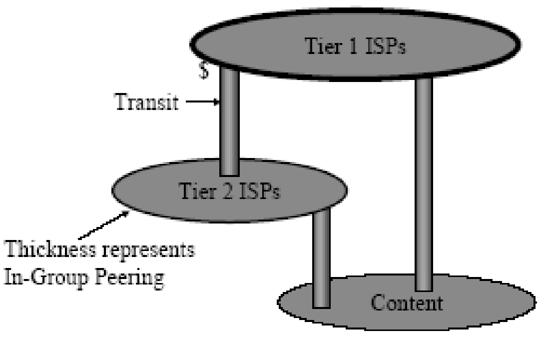

Figure 3 Generalized regional peering ecosystem, from Norton(2003)

3 The Peering Game

The purpose of the peering game is to enable students to gain some experience of the commercial and political side of the Internet. The scenario envisaged is that of a set of ISPs (Internet Service Providers) and transit network providers in an expanding market. The peering game is played to determine strategy, policies and peering contracts for network expansion and connectivity. This expansion may be enabled through bilateral or multilateral peering for example at a number of Internet eXchanges (IXs) where they can peer with other ISPs. Without peering the ISP must acheive connectivity through the transit network services provided by the two Telco operators, who provide transit services.

To complete the background for the peering game the students are presented with the papers from Bill Norton and in addition there were two guest lectures. The first was on the technical side of peering, with a discussion of Border Gateway Protocol 4 (BGP4) and how it is used, including policy aspects. The second guest lecture discussed the local political scene and aspects of service provision such as content delivery through the network. To complete the discussion on peering the students are also presented with broadband service provision information and the current state of peering in an advanced broadband market. This information is provided from the local telco (discussed further in section 3.2) and the evolution in peering due to the development of the broadband market is discussed in a paper by Kensuke, Kenjro & Hiroshi (2005) that is handed out prior to the class. In addition, basic background on gaming theory such as the Prisoner's Dilemma (Watson 2002) and signaling are introduced.

3.1 Learning Outcomes

The game, lectures and assessment were designed with the following learning outcomes in mind:

- An insight to peering policies on the Internet, with some specific reference to local issues
- An overview of the Border Gateway Protocol and how it is used by ISPs
- A perspective on strategies for dealing with network providers based on various inputs/analysis
- Skills allowing an analysis of network models for an ISP that allow the creation of, for example, a network design to last two or three game years
- Experience the use of oral and written communication skills through the game, negotiation and through the assessment deliverables

The game roles are the roles of peering/transit coordinator (as defined by Bill Norton of Equinix) and network designer but may include aspects of strategist/analyst, and management accountant.

3.2 Background

In the flat game world shown in Figure 4, we have two geographic regions in which Telco X and Telco Y provide transit network services to their respective ISP clients. For example each square could correspond to 100,000 potential residential and small/medium enterprise customers. In the game the two Telcos have developed domestic broadband services and have both been ordered to provide wholesale access to their broadband access services to other ISPs at cost in order to enable competition (e.g. by the regulator). This is effectively the case when the regulator forces the incumbent telco to be split into a lines company and a service company. The lines company is charged with providing all the players with the same service at the same price.

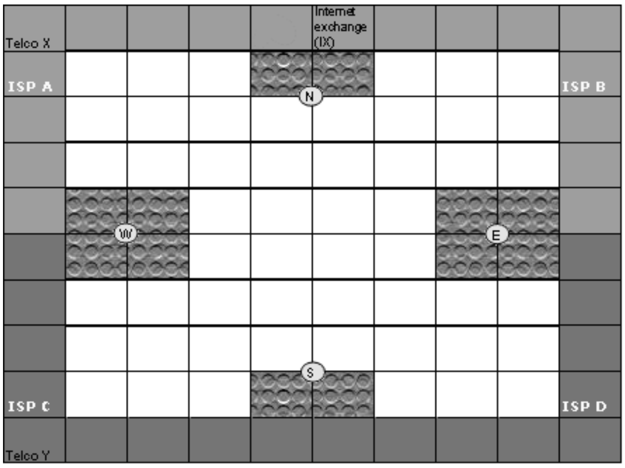

Figure 4 Game Space

The Telcos provide access to customers for the ISPs using an Unbundled Bitstream Service (UBS) under the terms and conditions defined by New Zealand Telecom (2004). In the game we assume that these broadband services are provided at fixed cost to the ISPs and the ISP revenue per square is fixed and in this version of the game the revenue per square is constant throughout the game.

In the game four ISPs have found funding and have been formed to take advantage of this opportunity to provide services to residential customers and to small and medium enterprises (SMEs). The ISPs are called ISP A, ISP B, ISP C and ISP D. Two of them are located in the Telco X geographic area and two are in geographic area of Telco Y. The ISPs have each selected an initial region (the corners of the board) for their first service deployment; this is where the game begins.

Four peering points (North, South, East, and West) have emerged in this network environment (for example, originally based on dialup ISP service provision and commercial interconnection). Peering points North and South are national peering points and East and West are international peering points. The ISPs can use these for bilateral peering arrangements; however the ISP must in this game build out their network infrastructure to reach the peering points. Note that as an alternative we could lease high speed connections to reach the peering points. However this game does not include the provision of high speed circuits as an option

We assume that the Internet content is available from Content Service Providers which are located at the peering points for arguments sake, and these content providers are accessed initially through the transit providers. Traffic from ISPs is exchanged through transit services until peering is established between ISPs. An ISP gets extra revenue for providing services to content providers (these are bonus squares, being around the peering points). Customers would like access to potentially all content and all other users on the network, so maintaining connectivity is a relatively high priority for all parties concerned in the game. Peering at multiple peering points is allowed and an ISP can occupy the same square as any other ISP.

At the start of the game ISP A and ISP B are buying transit from Telco X and ISP C and ISP D are buying transit from Telco Y. Note if telco's also played in this game they could compete for ISP transit services, for example by lowering their prices.

3.3 Playing The Game

In game theory a game is defined by the following set of attributes (Watson):

1. A list of players/teams
2. A complete description of what the players/teams can do (i.e. their possible actions)
3. A description of what the players/teams know when they act
4. A specification of how the players/teams actions lead to outcomes, and
5. A specification of players/teams preferences over game outcomes

Items one to four are defined in the handout given to the students at the start of the project, the fifth item is one which the students who play the game must assess as they play the game and can consist of a continuum of possibilities depending on their motivations, such as maximizing profit, gaining maximum market share, maximizing peering, minimizing transit costs, etc.

The stylised country map identified in Figure 4 where the teams play. In the real world the two telco's are usually ahead of the game in that they already have a nationwide rollout and have initially gained some sort of market share of broadband customers. However in this game we just play as the four ISPs.

The game space represents a country with a population in each square that has a propensity to purchase broadband Internet services. The following simple set of rules were used in the first running of the game:

- Each group plays the role of an ISP over a three game-year period, on a quarter by quarter basis.
- The price of transit services is fixed and the ISP pays for the traffic that is delivered to the ISP. The price that the transit provider charges is $1000 per unit of bandwidth. Each square on the board occupied by an ISP produces a unit of bandwidth.
- The price of wholesale services is fixed and the ISP gets $2000 revenue per square that they occupy.
- A content square (shaded) counts as an extra $2000 revenue.
- Each ISP secretly throws the die once per quarter and can occupy the corresponding number of game squares. The ISPs can only move adjacently and diagonally, and can occupy the same square as another ISP.
- If an ISP wants to peer then they forgo their throw of the die – they must instead negotiate a peering agreement. At the conclusion of a successful negotiation both ISPs complete and sign a peering agreement contract.
- One definition of the "winner" is the ISP with the

largest bank account at the end of the game. Sensible game play would be to calculate cost of not peering versus the cost of peering. One strategy is to make money by acquiring customers by expanding your ISP network and reducing transit costs by peering.

- When more than one ISP is present at a peering point any two co-located ISPs can negotiate bilateral peering:
  - There is a $2000 recurring cost of peering (per quarter) and a one-time fee of $2000 and the loss of 1 turn (i.e. if an ISP decides to peer it does not gain customers in that round).
  - Peering ISPs do not pay transit fee for each others traffic, so they save these transit charges from the Telcos.
  - One off payments. An ISP may agree a one off payment which is deducted from one of the ISPs and given to the other as part of the peering arrangement.

The game is played during class time. Each team sits together so that they can plan their strategy. At the beginning of each turn, every team must secretly throw a die that indicates the number of squares that they may take up on the board. The result of the throw is known only to the team and based on its result they can plan their strategy. The team can give away their advantage by groaning or exclaiming in delight, however, they soon learn to hide their knowledge.

The teams have a fixed time by which they must present their move to the coordinator. This means that they are under time pressure to complete their analysis, or forfeit their turn. The teams discuss where on the board they should expand and whether to consider forgoing a turn so that they can peer with another team. No other team knows about any teams strategy until it is revealed by the coordinator, or revealed through negotiations for peering.

The negotiations with the other teams take place either in the room or outside depending upon the preferences of the two teams. Once the coordinator has all moves she updates the game board and a spreadsheet that calculates the current revenue and cash flow for the ISP.

The game is played over multiple sessions to allow students time to reflect upon the playing of the game itself and their future strategy. Ideally the students should play the roles of the different ISPs in order to hone their strategy.

3.4 Assessment

There are three main elements to assessment: a game log recording the team's participation in the game; an individual report; and a group report. At the beginning of the game we make it clear that we are more interested in their observations upon the playing of the game than whether they made the most money or not.

After the game has ended, we have a class discussion about the game play. We consider questions such as: what were successful strategies and what are the real world constraints upon the application of these strategies?

3.5 Game Log and Group Report

Each team keeps a log of events in each turn and how their strategy is working. We provide a standard basic format for the log. Assessment is based upon completion of the log rather than the content.

Additionally, each team writes a report of the game played; this is a team effort and consists of around 2000 to 3000 words on the important aspects of the game from the team's perspective. This includes both group and inter-group game play and the game itself.

When assessing the game play and the game itself, we encourage the students to reflect upon the decisions by asking the following questions:

- Were the decisions correct or optimal?
- What would you change if you could go back in time?
- What are/were the consequences of your choices?
- Could you change your tactics to improve your teams' performance?

3.6 Individual Reports

Each student also produces an individual report. The purpose of the report is not to simply provide the same review of the game that the group report provided. The report consists of around 2,000 words and covers aspects of the peering game that the student may want to highlight, which may not have come out in the group report. It can include comment on the strategy of other teams etc. Some suggested topics are:

- Compare and contrast peering in New Zealand with the simulation in the peering game. How is real world peering different, and what would you change in the game?
- Identify how your network changes as you go through the game. For example: How does the BGP router deployment change? What is the routing policy and how does it change throughout the game?
- Imagine using the TelecomNZ Unbundled Bit Stream (UBS) service for a deployment in NZ. What would the network look like? This requires making some assumptions on deployment regions etc. and also knowledge of peering in New Zealand. Additionally, this topic requires consulting the UBS documentation.

4 Evaluation of the Peering Game

Fourteen postgraduate students who were enrolled in the class took part in the game. Following the game they were asked to evaluate their experiences with the game through an anonymous informal feedback questionaire. In general the feedback was positive with the students suggesting a number of key additions to the game to make it more interesting. The questionaire is provided in appendix 1.

Table 1: Questionnaire results (1=strongly agree, 5=strongly disagree), N = 16 students.

Question	***1***	***1.5***	***2***	***2.5***	***3***	***3.5***	***4***	***4.5***	***5***	***Avg***
Q6. Material covered in the peering game and lectures relates to the objective of this course.	5	0	9	0	2	0	0	0	0	1.8
Q7. The “peering game” and lectures have encouraged my study and interest in this subject.	5	0	6	1	4	0	0	0	0	2.0
Q8. For this level of course I have found this material intellectually challenging.	2	0	6	1	6	0	1	0	0	2.4
Q9. The “peering game” encouraged students to think creatively about this subject.	3	1	8	0	4	0	0	0	0	2.0

The results of the formative evaluation in Table 1 indicate that the peering game has in general achieved a positive learning experience. The lectures tied in well with the peering game itself (Question 6) and the general feedback was that real practitioner input was more valuable than a more theoretical exposition/analysis.

In question 7 playing the game achieved a positive effect on the study of the students. This transpired from several aspects, firstly the group pressure to be knowledgable about the state of game play, strategy and options, secondly the students in general found the game great fun, especially when they colluded to stop one team from winning. Question 9 asked the students about creative thinking within the game environment. Interestingly several students were very keen on sabotaging their competitors and several students became very business focused in that they analysed the optimisation of their cash flow and that of their rivals through spreadsheet analysis on a laptop. Providing computing resources whilst playing the game should be an useful extension.

Question 8 sought to identify whether the peering game was suitable for this level. The result here indicated that the game was probably not as challenging as other aspects of their classes. The students identified areas where they would like game enhancements. These are:

1. Competition for squares. This could be in terms of splitting revenue generated and also through splitting peering costs.
2. Geographic emphasis. Identify real user densities and their traffic scenarios such that there is more competition for the key customer regions.
3. Visibility of the game board and throw by throw checkpointing so that the game can be analysed in detail without students copying the sequence of moves.
4. More options regarding strategy. Suggestions included more options with regards to peering contracts and cooperation between ISPs.
5. Remove the randomness introduced by rolling the dice.
6. More time for negotiation, allow greater breadth for negotiations. More business rules and flexibility etc.
7. Play the game outside of the classroom setting (constraint of time and limited space allows strategy to be overheard and roll of the dice to be seen).

Based on this feedback and observation the following section identifies some of the enhancements that could be added to the game.

5 Proposed Game Improvements

Certain aspects of the game can be developed further, many of these possibilities were identified in the student feedback. These key extensions are discussed below:

Competition: in real life providers contend for the user population. Typically this is through price and feature differentiators. A version of the game has been developed which skews the user take up of service through the price differential in the marketplace. This can add the following aspects to the game:

- the cost of customer churn – in terms of the financial effect of loosing a customer to the competition.
- the setting of prices can be used as signals in the game between the ISPs based on the prisoners dilema and business strategy.

Geographic aspects can be enabled in the game, which can affect the choice of where to provide service. These are the factors that could be enabled:

- cost of deployment changes with geographical characteristics,
- limits on broadband services are a feature of geography (e.g. Rural broadband may be more bandwidth limited than urban broadband), see Kensuke et al for a discussion.

Advanced rules – to allow complex negotiation and enhancements to contracts, such as Penalty clauses, etc.

Extended playing time can be achieved by making the game play through a web interface, one per team. The teams can play from any location and their information is private. Only common information, such as prices, end of game-year results and so on are available globally. Time constraints are still essential, however can be lengthened to as long as one day. This would be in line with various Internet based business games such as the MERIT game in Civil Engineering (the MERIT website is at <http://www.merit.lboro.ac.uk>). To fully enable this game approach a means for online collaboration may be required, although as the game is only at one location face-to-face meetings would usually be practical.

Another improvement not identified by students but arising during the review of this paper is to examine how to relate “winning” to our learning outcomes rather than a monetary amount. One approach may be to propose challenges or to ask teams to play out certain strategies that they are secretly assigned.

6 Related Work

Games and simulations support experiential learning (Kolb 1984 and Race 2001) by simulating realistic problems (Nabeth and Angehrm 2004) and thereby addressing the time and scope constraints of setting a large project (Baker, Navarro & van der Hoek 2003).

The most similar work to ours is the “Problems and Programmers” game (Ibid.). This is a card game used to simulate the software engineering process. Our use of peering game and its evaluation closely parallels the use of evaluation of this game.

The card game was trialled in a software engineering class where lectures were used to establish concepts and theories before the game was played. The playing of the game was followed by an evaluation conducted using questionnaires. This evaluation of the game revealed that although the game was successful in reinforcing concepts learnt in lectures it was not as successful in introducing new knowledge. This was possibly due to a steep learning curve that students had to overcome in order to play the game and a lack of breadth in problems. Although our students did not report a steep learning curve for the game, our work has revealed similar results in that the game reinforced knowledge about peering learnt during the lectures but could be enhanced in ways that might improve game play and allow new knowledge and practice to be derived through game play.

7 Conclusions and Further Work

The Peering Game is an initial attempt at providing students with a mechanism to gain experience in aspects of Internet Service Provision, especially through peering, without having to start their own ISP. Our evaluation has shown that the board game is successful at motivating students and achieving learning objectives especially as it introduces some students to new aspects such as game theory, balance sheets and application of business mathematics. Furthermore, evaluation of the peering game has indicated a number of good points about its use within the class, and its development for use in the next year. One of our challenges is to enhance the realism of the game while keeping it both fun and simple to learn.

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9 Appendix 1 – Evaluation Questionaire

1. What aspects contributed most to the successful completion of the “peering game”?

2. What aspects were the greatest obstacle/s to the successful completion of the “peering game”?

3. What did you like best and least about working with your group for the peering game?

4. How would you rate the overall effectiveness of the peering game and associated lectures as a learning experience?

5. What are your feelings about the two introductory lectures? How did they help you in playing the “peering game”?

6. Material covered in the peering game/lectures relates to the objective of this course.

Strongly agree	agree	neutral	disagree	strongly disagree
1	2	3	4	5

7. The “peering game” and lectures have encouraged my study and interest in this subject

Strongly agree	agree	neutral	disagree	strongly disagree
1	2	3	4	5

8. For this level of course I have found this material intellectually challenging

Strongly agree	agree	neutral	disagree	strongly disagree
1	2	3	4	5

9. The “peering game” encouraged students to think creatively about this subject

Strongly agree	agree	neutral	disagree	strongly disagree
1	2	3	4	5

10. Please add any further comments that you think will help us in the future.