

# **The Integration of State Diagrams with Competency-Based Assessment**

**G. Kohli, D. Veal, S. P. Maj and G. Murphy**  
Edith Cowan University, Perth, Western Australia  
[g.kohli@ecu.edu.au](mailto:g.kohli@ecu.edu.au)

## **Abstract**

Hands-on units in Computer Networking technologies are increasingly popular amongst Computer Science students. However, to test the hands-on component it has been found to be necessary to use Competency Based Assessment (CBA). The hands-on exercises can become outdated very quickly due to the rapid advancement of technology. To offset such effects the authors have developed an abstract high level model to aid students' conceptual understanding across a range of technologies. These models are capable of providing state information of different internet networking devices e.g. switch, routers, and also to model routing protocols. The authors provide a method of integrating state diagrams along with CBAs.

## **Introduction**

As a reflection of the computer industry requirements there is an increasing emphasis on computer network and data communications in the Computer science curriculum. This has been supported by ACM / IEEE <sup>1</sup>. Networking courses are often based one ore more of the following areas as noted by Davis et al <sup>2</sup>:

- The OSI Model;
- Performance Analysis;
- Network Simulation

Within computer networking, data communication, Information Systems (IS), and management units the OSI model based instruction is very common <sup>3,4</sup>. Typically in this approach, the functionality of each layer of the OSI model is explained and then examples of this functionality in a specific network protocol are presented. A problem with the OSI Model is that it fails to provide new details with respect to protocols and functionality compared with the TCP/IP or Department of Defence Model except perhaps that the OSI model uses more layers. However, there are few, if any, implemented network protocols in which the actual architectural layers of a real system are strictly aligned with those of the OSI model. The OSI model provides the basis of layering networks and it also helps hardware and software designers to use a common framework for design and development of equipment. Most networking courses start by giving an overall overview of OSI model <sup>5,6</sup>.

On the other hand courses based on performance analysis use analytical based models that are often specialized in their area of application. This may involve the use of complex mathematics which may not be suitable or relevant to an employer's expectation for many computer networking students. However, its advantages include

the use by students of powerful mathematical tools. A major disadvantage is that these models may not be based upon real systems.

Simulation of computer networks provides students with the advantages of simulated observation of the operation of a network. Barnet<sup>7</sup> proposes the use of the NetSim simulator to support both major project assignments and more focused homework assignments. Whatever the simulation tool, a prudent technique is to incorporate the tool into supervised lab/project assignments, individual homework assignments, and classroom demonstrations<sup>7</sup>.

Although simulated environments have their benefits, real hands-on exercises give students a chance to apply the theory they learn from textbooks<sup>9</sup>. It has been noted that practical experience is necessary to fully understand network management problems, and that it is desirable to change the level of participation of students by increasing expectation and so making students more responsible for their own learning<sup>10, 11</sup>.

A possible approach to teaching computer networks topics is to allow students to learn using real networks. Traditionally, computer networks courses have not provided students with hands-on access to networking equipment and software; cost and implementations factors have made it difficult<sup>12,13</sup>. However, due to increasing popularity of vendor-based courses as components of undergraduate curricula, students now have the opportunity to study a more practical approach and hence program networking devices (switches, routers). Furthermore, relatively inexpensive equipment, such as switches and routers, and associated on-line vendor based curricula, such as Cisco Certified Networking Associate (CCNA), and the Cisco Certified Networking Professional (CCNP) are now readily available<sup>14</sup>. Furthermore, many students are studying networking and internetworking from a non computing science and even a non-technical background<sup>15, 16</sup>. Students doing the Cisco Networking Academy Program (CNAP) need to comprehend a large number of new concepts within a short time span. Each unit of a CNAP generally requires more time than is available under the university course structure. For example, in one university in Western Australia, four hours per week for 12 teaching weeks, for a total of 48 student contact hours, are allocated to deliver a one unit of CNAP program that Cisco recommend should take 70 hours. The CNAP program is based on a hands-on approach and mandates the uses of physical equipment (switches and routers) as part of the learning.

The hands-on approach to network technology education requires an understanding of switch and router operation. However, an analysis of educational materials<sup>17-19</sup> in this area has indicated that these devices are typically treated as 'black boxes'. Such an approach may not be best suited to the promotion of learning as this force student to construct their own mental model of the internal operation of such devices. These students constructions may or may not, be correct and may not be able to encompass future ideas. There is a need for students to develop a good conceptual model of networking devices.

## State Models

A high level abstract model has been developed to aid conceptual understanding. The state models implementation is based upon Finite State Machines (FSM)<sup>20</sup>. Using a FSM, network protocols can be modelled to exist in one of a number of defined states. These models are capable of providing state information of different internet networking devices e.g. switch, routers, and also to model routing protocols<sup>21, 22</sup>.

The state models present students with appropriate information which can facilitate understanding. Typically internetworking students are presented with the large quantity of information on typical router and switch screens as the result of user interrogation of these devices. The information presented can be quite complex and may require advance understanding. This is contrary to education theory which supports the need of abstraction in order to construct good understanding. With regards to abstraction the ACM notes *“Levels of Abstraction: the nature and use of abstraction in computing; the use of abstraction in managing complexity, structuring systems, hiding details, and capturing recurring patterns; the ability to represent an entity or system by abstractions having different levels of detail and specificity”*<sup>23</sup>. Furthermore, Rumbaugh et al define abstraction as *“Abstraction is the selective examination of certain aspects of a problem. “The goal of abstraction is to isolate those aspects that are important for some purpose and to suppress those aspects that are unimportant”*<sup>24</sup>.

Abstractions can be applied to computer and networking technology to help provide students with common fundamental concepts regardless of the particular underlying technological implementation. This helps to avoid the rapid redundancy of a detailed knowledge of modern computer and networking technology implementation and hands-on skills acquisition.

Maj et al have developed two states models based upon the principle of abstraction<sup>22, 25</sup>. In case of state model a PC can be modelled as a simple state device with a logical (IP) to physical (MAC address) Address Resolution Protocol (ARP) table and a Network Interface Card (NIC) table (IP address, Subnet mask and MAC address). The PC command *“IPCONFIG”* output directly maps onto these simple PC state diagrams. A router can then be modelled as a state diagram using the ARP and NIC table (as found in the PC) plus a routing table (figure 1). Hence an incremental learning path is provided. The router commands *“show arp”* and *“show ip route”* can be used to in conjunction with the diagrams to show the state changes as different networks are connected together.

Figure 5 Router State Model

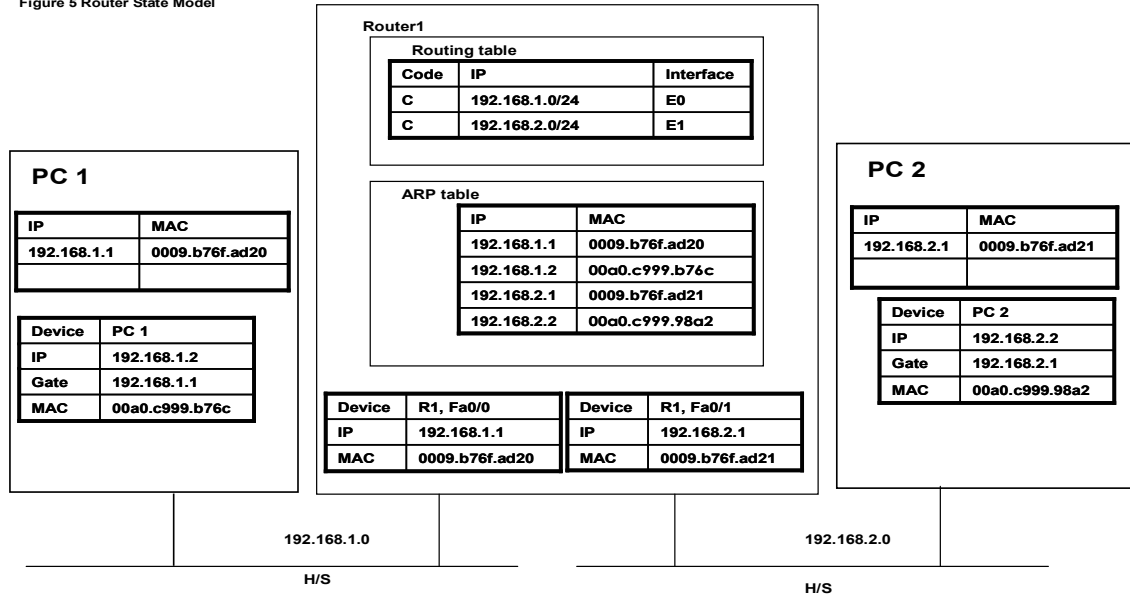


Figure 1: Router Model

The state models provide the basic understanding which the students can use to relate how internetworking system physically work.

### Competency based assessment

Competency has been defined as: *“The ability to perform in the workplace”*<sup>26</sup>.

Mirabile also defined competency as: *“A knowledge, skill, or characteristic associated with high performance on a job”*<sup>27</sup>.

Competency has been the cause of a great deal of controversy within higher educational institution in Australia. A 1995 Australian Government National Board of Employment Education and Training (NBEEB) report on the “Demand for and Dimensions of Education and Training” notes: *“Employers are increasingly emphasising a broad range of non-academic factors as more accurate indicators of a new employee’s potential to succeed in the workplace. ... They recruit on the assumption that graduates have satisfied the academic requirements of each institution, thus allowing them to focus on the particular skills and attributes they believe are most essential for the particular work environment. Generally, employers emphasise skills and attributes which are more difficult to evaluate than academic skills”*<sup>28</sup>.

Another report by Australian Government report *“Learning for the knowledge society: An education and training action plan for the information economy”* noted the importance of universities ensuring that graduates enter the workforce with the required competencies<sup>29</sup>.

Within the computer networking courses the practical hands-on assessment is gaining in popularity and Murphy notes: *That practical ‘hands on’ skills and knowledge is fundamental to conceptual understanding. That knowledge is more transferable to*

*different situations when acquired by a gradual process of conceptual understanding*<sup>30</sup>.

Furthermore, Tarrant favours the need of practical assessment: *In fact both practical skill and knowledge of certain principles are jointly sufficient for success. This should warn against any scheme in which practical knowledge is rigidly separated from theoretical knowledge*<sup>31</sup>.

The use of CBAs may place a large burden on the staff conducting them if the classes are large. It has been the authors' observation that in a class of 40 students it takes around 60 hours to conduct the actual CBA assessment. This was found to be the case during the current semester. The assessment time included setting up the laboratory between different assessments and ensuring that the equipment used during the assessments was working correctly. In regard to time constraints Osterich when discussing the Cisco Certified Internetworking Expert (CCIE) lab tests notes that *The lab exam takes place over two days. The first day the candidate has the task of setting up a complex internetwork using disparate technologies. During the evening of the first day, test administrators essentially sabotage the work you did in the morning, so the second day you spend troubleshooting and diagnosing those issues. The CCIE exam has a high failure rate: generally, more than 80% of first time candidates fail*<sup>32</sup>.

A further problem with the notion of competency is that of a common definition. Laver gives an example within Australian context<sup>33</sup>, stating that *Semantic confusion has arisen because the term 'competency' is used in at least three different senses: in the training sector, it means the capability to perform certain designated tasks satisfactory so that defined outcomes can be met; in the Mayer Committee's Report it covers more generic skills, such as problem solving and planning; and in the university sector, though generally rejected, it is sometimes recognised as comparable to such concepts as graduate attributes* Cited in<sup>34</sup>.

Secondly within the university sector the use of competency is not common as students are not often given credits based upon whether they can perform a task successfully or not. Understanding of the topic is regarded as more important, although some competency skills that can be offered as part of the unit are desirable. The later conditions should not be seen as mutually exclusive.

The authors decided to integrate the use of state diagrams as discussed above along with CBAs. The idea behind this assessment was to measure understanding of the topic covered during the semester. Furthermore, it allowed the authors to measure the student's ability to configure a physical network. Each student was given a case study on internetworking. The case study involved building the physical network and filling the appropriate information on to the state diagram provided.

The information could be obtained from the various Command Line Interface (CLI) outputs from the internetworking devices such as switches and routers. This information can then be transferred to the state diagrams. This allowed the students to produce a diagram of the physical network and also capture relevant information regarding that particular case study as required for the assessment.

## Evaluation

At the end of the assessment students were asked to fill in a questionnaire based upon their experience with this assessment. The results of the questionnaire are tabulated in Table 1.

Questions	Yes (%)	No (%)	Note Sure (%)	No Answer (%)
Number of students: 29				
Are you satisfied with various assessment instruments used as part of this course?	86.36	4.55	4.55	4.55
Are you satisfied with the timing of the assessment during the semester?	77.27	22.73	0	0
Do you only want practical assessment as part of this unit?	68.18	22.73	9.09	0
Has the assessment in this unit helped you in doing other assessment as part of your degree?	86.36	4.55	9.09	
Has the assessment helped you to improve your understanding of the topics covered in this unit?	86.36	0	0	13.64
Has the state diagram helped in better understanding the case study used in the assessment	80	0	0	20

Table1: Student Responses

Clearly a huge proportion of the students (86.36%) are satisfied with the methods used in the assessment. Furthermore, the use of state diagrams along with the assessment proved to a good mix of integrating understanding and competency. However, further investigation is needed as to the time problem which are not been addressed by this research.

## Conclusions

The hands-on units are becoming more popular in computer network courses and this necessitates the use of CBAs to assess hands-on skills. The use of CBA has both advantages and disadvantages. The authors proposed integrating state diagrams along with CBAs to measure student understanding. The initial finding have been promising and the authors are currently extending the scope of this research to factor out other issues associated with the use of CBAs, one of the most important of which is time management.

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#### GUPREET KOHLI

Gurpreet is a PhD student at Edith Cowan University with three years of experience in Lecturing and Developing Network and Data Communication units at Edith Cowan University. Gurpreet is currently investigating web services and capacity planning of e-business sites as part of his research at ECU.

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#### PAUL MAJ

Associate Professor S. P. MAJ is a recognized authority in the field of industrial and scientific information systems integration and management. He is the author of a text book, 'The Use of Computers in Laboratory Automation', which was commissioned by the Royal Society of Chemistry (UK). His first book, 'Language Independent Design Methodology - an introduction', was commissioned by the National Computing Centre (NCC). Dr Maj has organized, chaired and been invited to speak at many international conferences at the highest level. He has also served on many national and international committees and was on the editorial board of two international journals concerned with the advancement of science and technology. As Deputy Chairman and Treasurer of the Institute of Instrumentation and Control Australia (IICA) educational sub-committee he was responsible for successfully designing, in less than two years a new, practical degree in Instrumentation and Control to meet the needs of the process industries. This is the first degree of its kind in Australia with the first intake in 1996. It should be recognized that this was a major industry driven initiative.

#### DAVID VEAL

David received an honours degree in theoretical physics from the University of York in England. After completing a Post Graduate Certificate in Education from the University of Keel after which he lectured in physics at South Devon College UK for 10 years. He now lives in Western Australia where he has taught computing, mathematics and physics at high school level. He now lectures in computing science at ECU in Perth, Western Australia. His areas of research include: Competency-based assessment techniques in computing science, modeling of computers and networks to aid student understanding, and Graphical User interfaces for the partially sighted.

#### GEORGE MURPHY

George has a BSc degree from the Open University UK. He is a CCNA, CCNP and is a Cisco Certified Academy Instructor (CCAI). He now lectures on the CCNP units at ECU. He also lectures on the CCNP units at eCentral TAFE in Perth Western Australia. He has previously lectured on the CCNA, CCNP, Mathematics and Control Systems units at eCentral TAFE.