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Abstract of Doctoral Dissertation

RESEARCH ON CROSS-LAYER MANIPULATION MODEL IN TCP/IP ARCHITECTURE

TCP/IP アーキテクチャにおける
クロスレイヤ操作モデルに関する研究

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Global Information and Telecommunication Studies
Information Network System II

July 2011

The conventional Internet architecture is designed in a static environment: wired-line with stable electronic signals and low-speed stationary desktops not suitable for complex networking processing. In this rather stable environment, there is no meaningful control of the networking subsystem (NS) by communication applications. This results in the layering principles of the TCP/IP protocol stack, in which a protocol in a certain layer keeps the functions and internal states to itself.

While the layering principle facilitates well the development of the TCP/IP protocol stack as well as simple communication services such as email, news group, World Wide Web pages and real-time IRC, it does not provide any support for flexible or reliable services, such as fault-intolerant session-based application for which service developers must rely on special and often very complex mechanisms due to the almost zero support from the networking stack. Things get even worse when less reliable wireless access technologies, together with them are nomadic-related issues, become widely available.

These changes in networking environment, together with advances in processing power even for handheld devices, signal that the conventional model of self-contained, status-hiding layering approach of the Internet needs to be revised to provide applications with more cross-layer information and control to better adapt to the developments of the Internet realm.

In general, there are two objectives of a cross-layer system:

(objective-a) To allow exchange of information and possibly commands among layers so that a protocol instance of a layer can harmonize its activities with the condition of other layers.

(objective-b) To allow for the safe update (modification) of a protocol's parameter so that the internal state of a protocol can be altered and adapted to the changes of external environment.

While (objective-a) can optimize the performance of a protocol in particular or the whole system in general, (objective-b) allows the protocol to change its working environment from one setting/configuration to another, which in many cases means the protocol has evolved to another protocol. However, because the settings/configurations can be different from session to session, (objective-b) requires the cross-layer system to be able to identify and access an individual instance of a protocol (in the case the protocol has several instances running in the networking subsystem).

The purpose of this research is to propose a new TCP/IP architecture called the *InterLay model* that can facilitate the sharing and manipulation of information across layers' borders in a general, comprehensive and secure manner to support both (objective-a&b) discussed above. Some examples on the applications and coverage for future development of the new architecture (in Chapter 5) show that it can provide more service flexibilities over existing approaches. Moreover, because the control is not limited to local entities, it also opens the

possibility of better service coordination with external entities. In addition, the research proposes a methodology using the test questions to identify and categorize the type of parameters suitable for cross-layer manipulation.

Details of the organization of the dissertation are explained as follows:

Chapter 1: Introduction

This chapter introduces the history of the development of the conventional TCP/IP architecture, and how the principle of layering has facilitated the development of the Internet. This chapter also explores the recent changes to the Internet world, which makes the requirements of the layering principle too stringent. Finally, the objectives of the research are specified, which focus on addressing the above mentioned problems.

Chapter 2: Limitations of Conventional TCP/IP Architecture and Related Works

This chapter first explores the limitations of the layering principle in today communication environment, which prevent high layers from synchronizing their operations with the condition of lower ones. Because of the development of new services and hardware, there are cases where these limitations are not preferable. The chapter then explores results and also limitations the existing works that try to overcome the inadequacy of the TCP/IP layering principle. Some of these works focus on making changes to the architecture to adapt to a new feature on a case-by-case basis. Others, although of cross-layer information exchange approach, only support (objective-a) because they are not designed to identify an individual protocol instance or to support a secure way to access and alter the value of a parameter.

Chapter 3: InterLay Model for Cross-Layer Information Manipulation

This chapter provides the detailed design of the new InterLay model for TCP/IP architecture. The InterLay model will have to support both objectives explained above.

First, the reasons to use Object-Oriented (OO) Technology as the tool to analyze and design the new architecture are provided, the main advantage of which is that individual protocol instances are main players, implementing the protocol as an independent entity (i.e. object in OO Technology) makes it easier for the protocol instances to maintain their states as well as issue request to or react to request from other layers.

Next the detailed design of the InterLay entity which is consisted of three distinct functional groups, namely the Policy Element (PE), the Enforcer and the Informer, is explained. The PE is the checkpoint to authorize requests that can potentially affect the TCP/IP protocol stack (namely the update of parameter‘s value, executing a networking protocol procedures and registering for an event), as well as to authenticate the request from external entity. The Informer is in charge of returning the current value of the parameter, as well as informing the requester of the occurrence of a registered event. The Enforcer carries out the actual update or alternation of parameter value, as well as executes networking procedures. The InterLay model uses the Enforcer to support (objective-b) described above.

The Enforcer also contains security measures to safeguard its actions.

This chapter also provides the specifications of new system calls that allow the user application to control the underlying NS. Finally, the interaction scenarios between InterLay and various entities are provided.

Chapter 4: Test Questions for Selection of Fine-Tunable Parameter List

This chapter explains the need to find all the right parameters which will assist the developers in the service and protocol development process which can save development time for cross-layer services. Test questions are defined and used as a method to find those parameters. The test questions are then applied to various protocols in each layers of the TCP/IP protocol family. The parameters that are found are summarized for each layer.

One important aspect of the test question approach is that its methodology and results can be applied not only the InterLay but to any other systems that provide cross-layer control.

Chapter 5: Discussion and Analyses

This chapter first discusses the coverage of the InterLay model over the existing and potential future requirements toward the conventional TCP/IP architecture. It explores how InterLay supports mobility (including route optimization), fault-tolerance and insertion of SHIM Layer header. Advantages and benefits of the Interlay model are analyzed in comparison with related systems. The deployment strategies for the new architecture are also provided in two modes, namely disruptive and non-disruptive deployment. Some related issues on overhead in OO programming, performance and security are also discussed.

Chapter 6: Conclusions and Future Works

This chapter concludes the research, summarizing the major contributions of the research. One of the most notable contributions of the research is that the InterLay model is the only solution for cross-layer manipulation that supports the "write" operation of protocols' parameters. As a result the InterLay model can support new features by just using the programming skill instead of requiring a new protocol to be developed. And as recommended in Request For Comment 1958: "Nothing gets standardised until there are multiple instances of running code", the InterLay can be used in this sense to implement and monitor various aspect of a new feature, and the information obtained from this process can serve to speed up the development of the correspondent protocol. So the InterLay model can be used as a testbed to develop protocols for the TCP/IP architecture!

This chapter also specifies future works to fulfill the potential of the proposed architecture.

Lastly, some supplement information related to the operation of InterLay model as well as comparing its performance with and other proposals on maintaining TCP sessions over IP address changes are provided, analyzed and discussed in Appendix 1 and Appendix 2 respectively.

List of academic achievements

Category (Subheadings)	Paper Title
Articles in refereed journals	○ Vu Truong Thanh, Hidetoshi Yokota and Yoshiyori Urano, "Defining Cross-Layer Fine-Tunable Parameter List in TCP/IP Networking Architecture for Communication Service Optimization and Customization", Journal of Computer Science and Cybernetics, Vol. 27, No. 1, pp. 36-50, June 2011 ○ Vu Truong Thanh and Yoshiyori Urano, "Object-Oriented Approach to a New Cross-Layer Information Manipulation Model for TCP/IP Architecture", Forthcoming in GITS/GITI Research Bulletin 2011
Presentations at International conferences	○ Vu Truong Thanh and Yoshiyori Urano, "Mobile TCP socket for secure applications", The 12th International Conference on Advanced Communication Technology, pp. 971-974, Gangwon, Korea, Feb. 2010 ○ Vu Truong Thanh and Yoshiyori Urano, "Agent based handover scheme for SIP communication – The case of TCP sessions", The 24th International Technical Conference on Circuits/Systems, Computers and Communications, Paper Number: C-10-0599, session S16-D3, Jeju, Korea, Jul. 2009 ○ Vu Truong Thanh and Yoshiyori Urano, "Link-based service customization for NGN", The 10th International Conference on Advanced Communication Technology, pp.57-60, Gangwon, Korea, Feb. 2008

	Vu Truong Thanh and Yoshiyori Urano, "Agent based low loss low delay handover scheme for SIP communication – The case for UDP traffic", The 11th International Conference on Advanced Communication Technology, pp. 2099-2102, Gangwon, Korea, Feb. 2009
Presentations at International conferences (No refereed)	Vu Truong Thanh and Yoshiyori Urano "Development of "Next Generation Network Basics" e-Learning Courseware based on cooperation among AIC members", Asia Info-Communication Council 35th Conference, Document Number 215, Saitama, Japan, Mar. 2007 Vu Truong Thanh and Yoshiyori Urano, "Distant E-Learning and Information sharing by Geographic Information System on Community Network in rural area, Asia Info-Communication Council 35th Conference, Document Number 216, Japan, Mar. 2007 Vu Truong Thanh and, Yoshiyori Urano "Experiment of Session Initiation Protocol's instant messaging", Asia Info-Communication Council 32nd Conference, Document Number 143, Halong, Vietnam, May 2005

Others	KDDI, Waseda University, NIICS, "Joint Research on an Advanced Learning & Training System based on Social Networking Site service, Hanoi, Vietnam", Final Report, Asia Pacific Telecommunity Project, Nov. 2009, Hanoi, Vietnam KDDI, Waseda University, Phutho P&T Dept., "Distant E-Learning and Information sharing by Geographic Information System, Phutho, Vietnam", Final Report, Asia Pacific Telecommunity Project, May 2007, Phutho, Vietnam Waseda University (Japan), Posts and Telecommunications Institute of Technology (Vietnam), "NGN Advanced", E-learning Material, Feb. 2008, Tokyo, Japan Waseda University (Japan), Posts and Telecommunications Institute of Technology (Vietnam), "NGN Basics", Feb. 2007, Tokyo, Japan Waseda University (Japan), Universiti Malaysia Sarawak (Malaysia), "IP-Mobile Advance", Mar. 2006, Tokyo, Japan Waseda University (Japan), Posts and Telecommunications Institute of Technology (Vietnam), "IP-Mobile Basics", Mar. 2005, Tokyo, Japan