

Software-Defined Dynamic Bandwidth Management

Yao-Chung Chang*, Yung-Chiao Chen**, Tsung-Hau Chen***, Jiann-Liang Chen**, Shih-Ping Chiu** and Wei-Hsiu Chang**

*Department of Computer Science and Information Engineering, National Taitung University, Taitung, Taiwan

** Department of Electrical Engineering, National Taiwan University of Science & Technology, Taipei, Taiwan

*** Department of Computer Science and Engineering, National Taiwan Ocean University, Keelung, Taiwan

ycc@nttu.edu.tw, chenyc@ntu.edu.tw, 00457145@mail.ntou.edu.tw, lchen1215@gmail.com

Abstract—This work develops a software-defined mechanism for dynamic bandwidth management, abbreviated to SDBM. This proposed SDBM mechanism was realized using the OpenFlow architecture and the OpenWrt platform. The resource allocation procedures and weighting policy were designed using SDN Controller to perform bandwidth management. This mechanism firstly monitors and analyzes networks and the statuses of applications and then, based on the results of the analysis, dynamically reallocates resource with software-defined discipline. Based on our simulation results, bandwidth utilization is improved and packet loss reduced by 12.4% and 8%, respectively.

Keywords- Software-Defined Dynamic Bandwidth Management (SDBM), OpenFlow, OpenWrt Platform

I. INTRODUCTION

Owing to the rapid development of multimedia technology, many multimedia applications are available on the Internet, such as VoIP, videoconferencing, video on demand, distance learning, electronic commerce and many more. Different applications have different bandwidth requirements and the demanded network service quality is increasing.

Bandwidth management for a long time has been a difficult goal to achieve. Some of the latest network applications, such as videoconferencing applications, are demanding high-quality network service but, despite the availability of many network services and networking equipment, service quality is still not widely applied to today's network architecture, mainly because of the need to set bandwidth manually; the difficulty of doing so, the large number of devices to be set, and the lack of professional knowledge of the network administrators, which leads to human error, causes services to be interrupted and allows only rough service quality assurance to be provided.

Presents solutions for bandwidth management involve physical network isolation and excessive network configuration are achieved, such as using a data center that stores data and has its own dedicated network, dedicated hardware and communications protocol, such as fiber channel storage and the high performance computing transfer of InfiniBand. However, these solutions not only increase installation, management and operating costs significantly: they do not allow multiple applied networks to transfer using the statistical multiplexing method, resulting in poor

utilization of available network bandwidth and repeated use of network resources.

Some advanced bandwidth management schemes can support only DiffServ-like class-based flow control. Even a very small flow control action will require the complex manual configuration of network equipment. All network equipment may support bandwidth management, but not the automatic adjustment of bandwidth and setting of rules. Since a traditional network cannot meet current service and management requests, the concept of Software-Defined Networking has developed [1-3]. This work improves the flexibility of bandwidth management using software-defined management architecture [4-7]. The proposed mechanism, called Software-Defined Dynamic Bandwidth Management, or SDBM, will schedule resources according to types of services and the software-defined controller will dynamically adjust the bandwidth of the overall network according to the given scheduling. This SDBM mechanism was implemented using OpenFlow architecture and the OpenWrt platform [8].

II. DEFINITION AND FORMULATION

Dynamic Bandwidth Management (DBM) is a technique for managing bandwidth configuration that has attracted substantial interest. DBM reallocates bandwidth using various dynamic bandwidth management strategies, yielding a network environment without congestion or bandwidth that is not consumed by a particular application. Table 1 presents literature relevant to DBM.

TABLE 1. DBM-RELATED RESEARCH

Dynamic Bandwidth Management	Literature (advantages and disadvantages)
Dynamic Bandwidth Management for Single-hop Ad Hoc Wireless Networks [12]	This research is to adjust the allocation ratio of the channel time in respect to bandwidth requirements of each flow. However, this research does not consider the existing issue of network integration, environment restriction is only at ad-hoc wireless network environment.
Application of Rate and Buffer Occupancy Measurements in Congestion Detection and Management: A Simulation Study [13]	This research discusses the DBM mechanism. It combines the benefits of both the arrival rate and the buffer occupancy to provide a simple bandwidth management. However, both the boundary value of the rate and the buffer are not dynamic configuration.

A Dynamic and Adaptive Bandwidth Management Scheme for QoS Support in Wireless Multimedia Networks [14]	This research selects the one which can supply the most bandwidth among the flow that have the same priority order to reduce the bandwidth of the one that with the most bandwidth. In addition, by setting compensation time, the possibility of a change of performance in a short time by a single flow will reduce significantly, but can only to manage in a single wireless network equipment.
Improving the Performance of a Dynamic Bandwidth Management Scheme [15]	This research presents the time interval parameter of a dynamic measurement and the parameter of the dynamic bandwidth management. The setting of the parameter can affect the performance of dynamic bandwidth management. Although it provides the concept of the dynamic bandwidth management mechanism, but has no actual operation procedures.
Real-Time Bandwidth Management Middleware for Multi-session Isochronous Streaming Service in the IEEE1394-based Home Network [16]	This research presents the middleware of immediate flow management, RTSM. In order to deal with the shortage of bandwidth, the RTSM uses two methods to allocate the bandwidth dynamically: 1. The bandwidth management function measures the usage rate of network bandwidth and restores the residual bandwidth. 2. The isochronous streaming scheduler manages all streaming services in a network according to a priority-based preemptive scheduling policy. But it is only for home network and only operates on PC.
Performance Study of Dynamic QoS Management for OpenFlow-enabled SDN Switches [17]	This paper studies switch diversity while deploying dynamic QoS mechanisms for TCP flows in an OpenFlow-based network. It evaluates two QoS techniques. This paper don't propose bandwidth management dynamically and only focus on TCP connections.
Bandwidth Control and Regulation in Mobile Networks via SDN/NFV-Based Platforms [18]	This paper addresses the mobile operator need for regulating and managing traffic for better QoE. It deployed SDN and NFV platform to mitigate the effects of encryption. This paper don't give a general purpose DBM scheme.

The proposed system has an OpenFlow architecture and an OpenFlow controller. The application modules on the OpenFlow controller are based on the SDBM mechanism that is designed in this study. Figure 1 presents the proposed SDBM architecture; an OpenFlow controller is used to develop the application control modules. First, the Nodes Network Data Monitor collects information about network status (number of nodes, bandwidth usage and other variables) at each node in OpenFlow networking; this collected information is analyzed by the Deployment Analysis Module, which uses the User Application Score Module to assign scores to user applications. The Bandwidth Utilization Data Module evaluates the bandwidth usage of each node. Finally, the Policy Decision Module allocates bandwidth to all OpenFlow nodes and passes this information to the Bandwidth Allocation Policy Agent to change the bandwidth control rules in the Flow Table for all OpenFlow nodes via a secure channel.

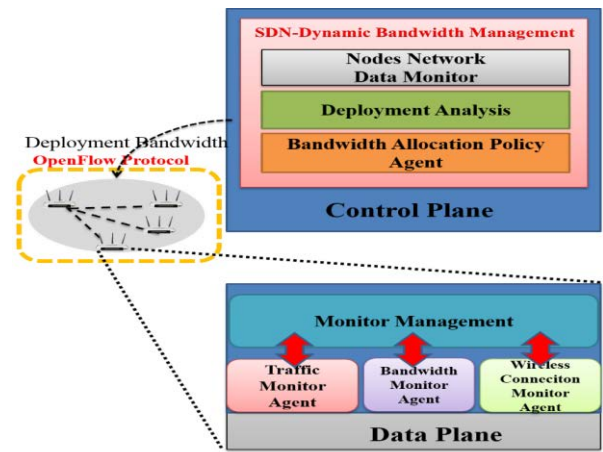


Figure 1. SDBM System Architecture

Table 2 defines the symbols that are used in the proposed SDBM mechanism. The operation of the SDBM system comprises four steps shown as Figure 2-5. First, in the initialization of bandwidth allocation, the SDBM mechanism sets the initial bandwidth based on the number of nodes and the current network bandwidth. Step 2 detects the number of applications and their types at each node and then assigns a score to each application according to a weighting mechanism. Step 3 categorizes nodes as bandwidth providers, bandwidth requesters or nodes that do not need bandwidth adjustment in response to the detected usage. Finally, SDBM dynamically adjusts the bandwidth according to the score of each node. The operations of the systems are described below.

TABLE 2. THE SYMBOLS THAT ARE USED IN THE SDBM MECHANISM

Symbol	Definition
D_t	Total number of nodes
P	Total network bandwidth
n_t	Total number of connections of all nodes
n_i	Number of connections of node i
P_{Mini}	Minimum guaranteed network bandwidth of node i
P_{Max}	Maximum network bandwidth of node i
γ	Minimum bandwidth allocation ratio
P_{av}	Average bandwidth allocates to node i
W_{di}	Weighting value for node i
α	Lower limit of bandwidth usage
β	Upper limit of bandwidth usage
$RE\{\dots\}$	Set of bandwidth requesters
$PR\{\dots\}$	Set of bandwidth providers
re	Amount of bandwidth requesters

pr	Amount of bandwidth providers
U_i	Bandwidth usage of node i
B_{ui}	Currently used bandwidth of node i
$pr(i)$	Bandwidth provider of node i
$r(i)$	Bandwidth requester of node i
r_t	Total amount of requested bandwidth
pr_t	Total amount of provided bandwidth
U_{avi}	Bandwidth usage of node i

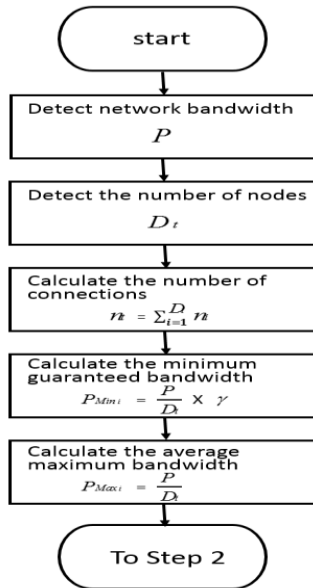


Figure 2. Procedure of Initial Bandwidth Allocation

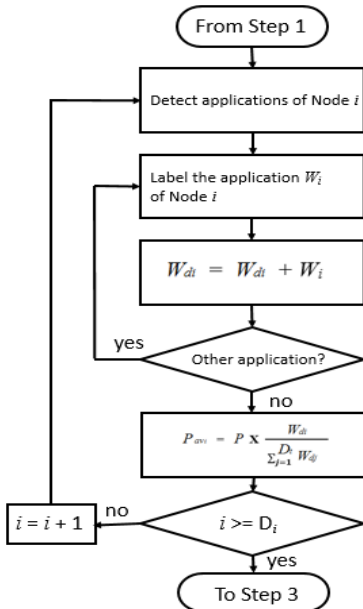


Figure 3. Procedures of Bandwidth Allocation via Weighting Policy

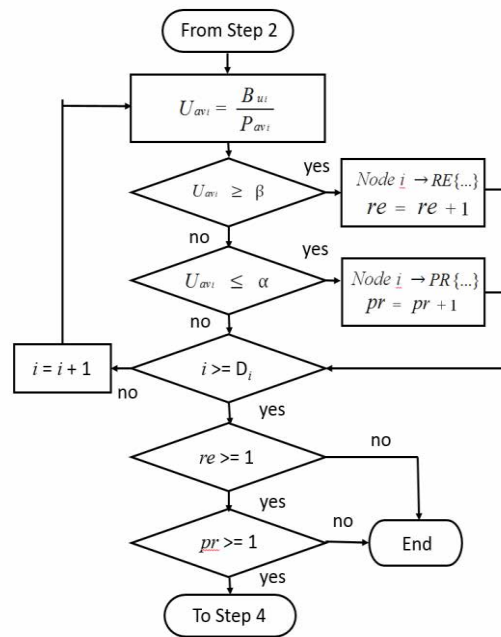


Figure 4. Procedures of Nodes Categorization According to Bandwidth Usage

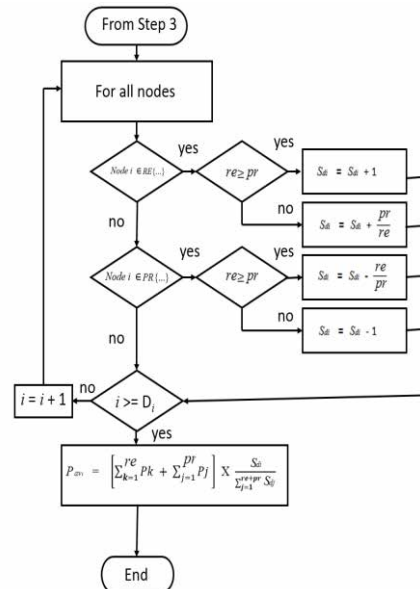


Figure 5. Procedures of Bandwidth Adjustment via Scoring Mechanism on Usage

III. PERFORMANCE ANALYSIS

Figure 6 presents the simulation environment in this study. The wireless network includes three blocks. Each block with a TP-Link1043NDA1 device, that supports OpenFlow1.3.0 Spec., multiple laptops with wireless network adapters and mobile phones. These devices request various internet services and then evaluate the network performance. The network bandwidth in this work is 60Mbps.

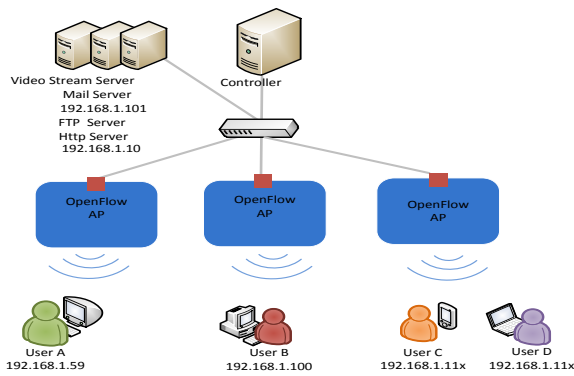


Figure 6. Simulation Environment

Figure 7 shows bandwidth usage and performance with and without SDBM. In the same network environment, the average bandwidth increases by 12.4% from 50.8% (without SDBM) to 63.2% (with SDBM).

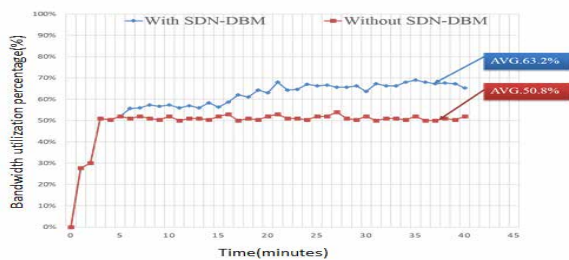


Figure 7. SDBM Bandwidth Usage Comparison

Figure 8 presents the packet loss analysis in the full streaming network environment with and without SDBM. The bandwidth is fully loaded without SDBM, resulting in almost no change in packet loss all the time, and an average packet loss of 19%. SDBM dynamically adjusts the bandwidth when the streaming service is full. The packet loss is gradually reduced to an average of 11% by bandwidth adjustment. Thus, SDBM under this simulation network condition reduces packet loss by 8%.

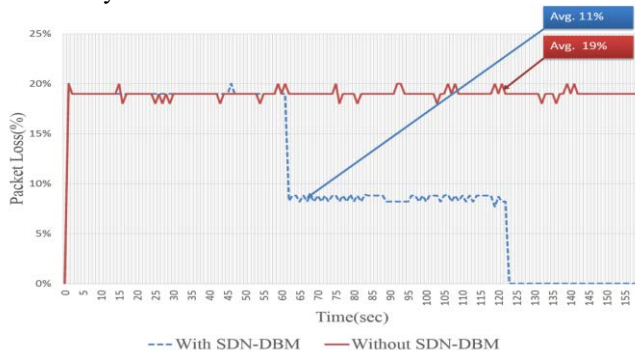


Figure 8. SDBM Packet Loss Analysis

IV. CONCLUSIONS

With advances in interconnection technology for networks, the complexity and maintenance costs of traditional decentralized network structures are increasing. Even when network administrators have extensive networking knowledge, the allocation of bandwidth to many network nodes is very

time-consuming. Moreover, even when the network administrators have set up the bandwidth allocation rules, the static bandwidth that is provided in the network environment cannot always meet the demands of users. For this reason, this work proposes a Software-Defined Dynamic Bandwidth Management mechanism on OpenFlow network architecture to perform flexible dynamic bandwidth allocation. This mechanism allows network managers to adjust the bandwidth of all network nodes to reduce significantly network maintenance costs and the complexity of the setting of the network bandwidth. It also provides dynamic and flexible bandwidth adjustment to meet the bandwidth demands of users. The SDBM mechanism that is developed in this work has realized the goal of dynamic bandwidth allocation management. It not only guarantees minimum bandwidth, but also can adjust the maximum usable bandwidth in a manner that takes into account the current network state and can dynamically adjust the bandwidth of each node on the software-defined controller. The SDBM mechanism herein increases bandwidth utilization and reduces packet loss by 12.4% and 8%, respectively.

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Dr. Yao-Chung Chang received B.S. degree (1992-1996) of Computer Science and Information Engineering from Tamkang University (TKU), Taipei, Taiwan. After that, Dr. Chang completed his M.S. degree (1996-1998) and Ph.D. degree (2002-2006) of Computer Science and Information Engineering from National Dong Hwa University (NDHU), Hualien, Taiwan. In 2006, Dr. Chang joined the

Department of Information Science and Management System (ISMS), National Taitung University (NTTU), Taitung, Taiwan, as an Assistant Professor. In 2007, He joined the Department of Computer Science and Information Engineering (CSIE), National Taitung University (NTTU) as an Assistant Professor. Also, he served as the Director of Computer Center and the Director of Taitung Regional Network Center, National Taitung University since Aug. 2009 to Jul. 2011. Besides, Dr. Chang is a recipient of the subsidization program in universities for encouraging exceptional talent, Ministry of Science and Technology, Taiwan (2010-2018). Dr. Chang has been the session chair of 25 international conferences, the program committee of 93 international conferences, and the reviewer of 64 international conferences. He has published more than 45 papers in international journals and conferences. Also, he received the Outstanding Teaching Award from National Taitung University. His primary research interests include Intelligent Communication System, IoT and Cloud Computing.



Yung-Chiao CHEN was born in Taiwan on September 6, 1963. He received the M.S. degree in Electrical Engineering from National Taiwan University, Taipei, Taiwan, in 1988. He is currently an associate professor at the Computer and Information Networking Center, National Taiwan University, Taipei, Taiwan. His current research focuses on SDN and Fault-tolerant WDM networks.



Tsung-Hau CHEN is a undergraduate student at the Department of Electrical Engineering, National Taiwan University of Science & Technology, Taipei, Taiwan. His current research interests are Machine Learning, SDN, AI in Biotech.



Jiann-Liang CHEN was born in Taiwan on December 15, 1963. He received the PH.D. degree in Electrical Engineering from National Taiwan University, Taipei, Taiwan in 1989. Since August 2008, he has been with the Department of Electrical Engineering of National Taiwan University of Science and Technology, where he is a distinguished professor now. His current research interests are directed at cloud computing, wired-wireless communication and networking and Internet of Things

Wei-Hsiu Chang received the M.S. degree in Department of Electrical Engineering of National Taiwan University of Science and Technology. His research focuses on SDN.