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Software Defined Network Application in Hospital

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Summary: Not only conventional computer system (i.e. Electric Medical Record, Physician Order entry, PACS), but also other medical equipment including ECG,US, EEG, X-ray and many others, are on-line now. Extensive use of computer network exacerbates complexity of programming computer network equipment.
While healthcare service becomes more dependent on information technology, such complexity can result in network failure that interrupts health service. Recently, concept of Software Defined Network (SDN) has widely been accepted by network equipment supplier and production quality network equipment appeared in the market. SDN is a concept of programmable computer network fabric, in other words, network that can be dynamically reconfigured by downloading the settings from the controlling computer. We have introduced SDN in our hospital network to evaluate its utility and stability. After introduction of SDN, SDN segment turned out to be stable, and automatic rerouting avoiding failed route was far quicker than conventional technology. Our conclusion is SDN is highly valuable technology in healthcare, that is 24hr/365day mission critical business.

1 Introduction

Modern computers and devices communicate with each other using IP network. Traffic on IP network is replicated with repeater, controlled with routers and switches. UTP cable, STP cable, optical fiber, radio wave and other media transfers such traffic as signal. Routing of IP packets is defined on each routers and switches as configuration. Such devices observe activities of each devices and network traffic using various protocols including RIP, OSPF, BGP4, MPLS and so on. These complexity lead to cost spent on network management and leaves chance of inappropriate configuration.

Programming language that describes the behavior of switches and routers, and routing logic stored in each switches are different by switch supplier as well. As suppliers define their own routing program language for their switch product, consistent network programming becomes markedly difficult.

Recently concept of Software Defined Network (SDN) is gaining attention so as to add flexibility and control to computer network. Conventional switches have data exchange function and exchange control function. SDN is a concept to separate exchange function and exchange control function. SDN controller of SDN stores routing logic and delivers logic to each SDN switches that only have minimum and simple interpretation function of such logic and concentrate on delivery of data between each switch ports. SDN controlling computer (SDN controller) assesses the state of network and modifies behavior of SDN switches based on assessment. With such controlling computer, network resources like bandwidth, ports and physical lines, appliances are optimized so as to realize appropriate recovery from failure, target QoS, etc.

OpenFlow is one of major technical specifications of SDN[1,2] published by Open Network Foundation (ONF). OpenFlow is an open source project developed in the collaboration of Stanford University and the University of California Berkley. ONF is a consortium of private companies and founding member originally consisting only of network users, i.e. Deutsche Telekom, Facebook, Google, Microsoft, Verizon, and Yahoo!, aiming to develop practical standards of OpenFlow specification and promotion of its utilization. ONF now expands its membership to equipment suppliers and users like CISCO, INTEL, IBM, NEC, HP, FUJITSU, HUAWAI, JUNIPER, ORACLE, Vmware, Orange and so on.

According to OpenFlow specification, routing logic is based on combination of 12 types (version 1.0) to 15 types (version 1.2) of data packet attributes(port ID where the data came, source machine address (MAC), destination MAC, source Internet address (IP address), destination IP address etc.). OpenFlow controller stores such routing logic and down loads such routing logic to each OpenFlow switches. OpenFlow switch receives assigned routing logic and listen, monitor, analyze and forward data packet between switch ports. Results of monitoring by OpenFlow switch are sent to OpenFlow controller. OpenFlow controller analyses network status including link failures, switch failures, loop etc. and change routing logic according to the predefined program.

SDN is now gradually applied in datacenter and carriers but application as campus network or LAN are still small in number. The Stanford University introduced SDN as experimental LAN on Campus Research LAN and our hospital, Kanazawa University Hospital is also using SDN 24 hours/ 365 days as LAN.

Healthcare organizations rapidly adopt information technology (IT) recent years, to reduce operational cost of healthcare services and to control quality.

In academic medical centers in Japan, EMR (Electronic Medical Record) systems are widely accepted. Physicians now enter prescriptions, place lab exam orders etc. into the EMR systems, making them very dependent on these systems.

Medical equipment are also rapidly adopting processors within it. Medical equipment using micro-processor have function to monitor and calculate monitored value, interpret the value and exhibit the evaluation of measurement. Such intelligent medical equipment greatly helps physicians and other healthcare professionals.

Not only conventional computer utilized for EMR etc. but also intelligent medical equipment are connected to each other through computer network. Such expansion of online equipment cause frequent modification of network and complex segment division. Medical equipment suppliers, expecting to reduce installation cost by isolating their equipment from other computers, frequently deploy their own private physical network. Such behavior adds more complexity.

As healthcare organizations have introduced large numbers of medical equipment and computers recently, stable computer network is becoming quite important.

In case inconsistent routing logic was deployed, data can be lost among the forest of network and can result in network loop and entire network down. Consistency must be kept. Kanazawa University Hospital occasionally experienced such packet storm and loop, un-identified packet that led to total system down or unstable routing.

To resolve such complexity, essentially coming up with wide utilization of information devices including smart devices in healthcare setting, new technology and methodology are expected. Acceptance of SDN/OpenFlow in network equipment supplier is one of promising technologies that manage or resolve such complexity. While experimental SDN switch products have appeared and have been evaluated for years, production quality SDN switch finally appeared only two years ago.

Expecting to resolve expanding complexity of computer network, we evaluated stability and flexibility of SDN with OpenFlow switches.

2 Method

In 2012, one building (GRBI: General Research Building Phase I) housing Labs of clinical department and faculty room was newly built. We introduced OpenFlow network to this building as hospital in-house LAN. OpenFLow switches and controllers were purchased from NEC that was only production quality OpenFlow switch and controller supplier at the time of contract.

OpenFlow network consists of 16 OpenFlow switches, 2 OpenFlow controllers, 2 controlling network switches with optical fiber connection. OpenFlow network was connected to access LAN and attached to core Layer 3 switch using link aggregation. Conceptual logical network is shown in Figure. 1. Physical configuration is shown in Figure. 2.Anesthesia, Ophthalmology, Radiology requested their departmental private network to be introduced in GRBI. While such departmental networks were deployed using independent physical wires and switches in the old building, they are realized with Virtual Tenant Network (VTN) function of SDN that is completely independent from physical topology of switches.

3 Deployment, stability, function and cost as result

3.1 Deployment

The building was released from the construction company to the University on March 1, 2012. Deployment started after this release and the building had its grand opening on April 1, 2012 on schedule, and have been utilized since then for operation. While specification of departmental private network was not finalized until mid-March, network was released fully on schedule. This shows the flexibility of computer network configuration.

3.2 Function

Using Virtual Tenant Network (VTN) function, four private networks were prepared on single physical network with OpenFlow switch. Relocation of computer does not require physical wiring change. It can be done with changing the entry of VTN.

To increase redundancy of the network after the release, intentional rewiring of network optical fiber was done. This rewiring caused routing changes between the switches. In case of conventional switches, such rewiring may need 1 to 2 minutes to stabilize the automatic rerouting (using STP), where OpenFlow network responded immediately and routing change occurred within seconds.

3.3 Stability of Switch and other OpenFlow Equipment

We continuously monitored network equipment to evaluate stability of the OpenFlow switches. OpenFlow switch incident occurred in November of 2012 on one of the 16 OpenFlow switches after seven months of operation. It was a switch processor failure. Failure rate was compared with the existing conventional switches supplied by Allied-Telesys Co. Ltd. using Generalized Wilcoxon test. We were not able to find statistical difference in the failure rate ($p = 0.18757$) . (Figure 3)

3.4 Cost

Introduction of OpenFlow network was done with the same budget of 34M JPY including wiring fabric over the building as the estimation with the conventional technologies. Operational cost based on working time of Systems Engineers was markedly reduced to almost zero during one year of operation.

4 Discussion and Perspective

4.1 Experience overview

With our experience of replacement of hospital LAN with OpenFlow network, computer network for hospital information system as infrastructure was successfully merged into one OpenFlow network, migration process was tested also successfully with modest cost. Reliability of network service was improved substantially compared with the conventional equipment by improved failover time of network path and the same reliability of OpenFlow network equipment. We are planning replace entire hospital network with SDN in two years. (Figure 4)

4.2 Impact of SDN on Healthcare

In healthcare organization, multiple endpoints, such as observed objects (human, medical equipment like infusion pump and vital monitors, image modalities, environmental monitors etc.), network equipment (switches, routers, Wi-Fi AP, IDS, mobile) and servers act independently while interconnected.

SDN enables separate transfer of data flow from control of data flow. Then users can centrally monitor the data flow, define behavior of the data flow and instruct switches to realize expected data flow with SDN.

Then healthcare organizations can control entire enterprise network realizing immediate switch of network path and QoS by introducing one integrated SDN network and slicing it into separate multiple virtual network without changing physical network configuration.

Several characteristics of healthcare services may add more value to SDN application in healthcare than in other fields.

Endpoints attached to patient and staff continuously move around in the facility and sometime even to the outside of the healthcare organization. Recent experiments of MobileFirst Future Internet Architecture project by NSF integrate Wimax and Wi-Fi using OpenFlow. SDN may help simple control method to location free integration of information endpoints so that patients can be monitored seamlessly from home to the hospital even across the border integrating Wifi, Wimax and Mobile (3G, LTE etc.) communication. OpenFlow and SDN will eliminate or limit the need of MPLS, BGP, OSPF or RIP and simplify such mobile – fix line communication hand over.

According to rapid change of technology for diagnosis and medical procedure, medical equipment need update and replacement . Not only replacement of the medical equipment, but relocation of the medical equipment by organizational and operational reason affect network configuration. SDN will reduce engineering work by MAC based automatic network configuration.

Social pressure on healthcare organization to serve community based services needs inter-connection to computer system outside of the organization. Such connection requires complex security consideration. As data flow can be controlled with SDN, access control can be simplified and expensive resources like firewall and load-balancer can be utilized optimally. Such control over data flow finally reduces the cost of IT expenditure of healthcare organization.

4.3 Issues for future

When SDN will be widely applied in organizational LAN, flow table in each switch will expand. This may result in performance deterioration of OpenFlow switch. To achieve performance, several techniques like scope limitation and division of flow table are considered. OpenFlow controllers also need to handle expansion of network with rapid handover in case of its failure, management of multiple domain, version and vender compatibility.

Such issues are being discussed in the community, and some of them are resolved using OpenFlow Specification version 1.3 and after.

5 Conclusion

We introduced Software Defined Network (OpenFlow network) to our university hospital. It was stable and help the computer network to be kept simple. Cost needed was almost the same as the conventional switch network at initial, but substantial reduction of operational cost is expected. SDN (OpenFLow network) can be realistic and ideal technology component for hospital computer network that face expanding on-line equipment and computers.

6 Reference

1. Open Networking Foundation. Software-Defined Networking: The New Norm for Networks. ONF White Paper. Open Networking Foundation. April 13, 2012. https://www.opennetworking.org/images/stories/downloads/sdn-resources/white-papers/wp-sdn-newnorm.pdf (Online Material. Viewed 15 May 2013)

2. Open Networking Foundation. OpenFlow Switch Specification Version 1.3.1 (Wire Protocol 0x04). Open Networking Foundation. September 6, 2012. https://www.opennetworking.org/images/stories/downloads/sdn-resources/onf-specifications/openflow/openflow-spec-v1.3.1.pdf (Online Material. Viewed 15 May 2013)

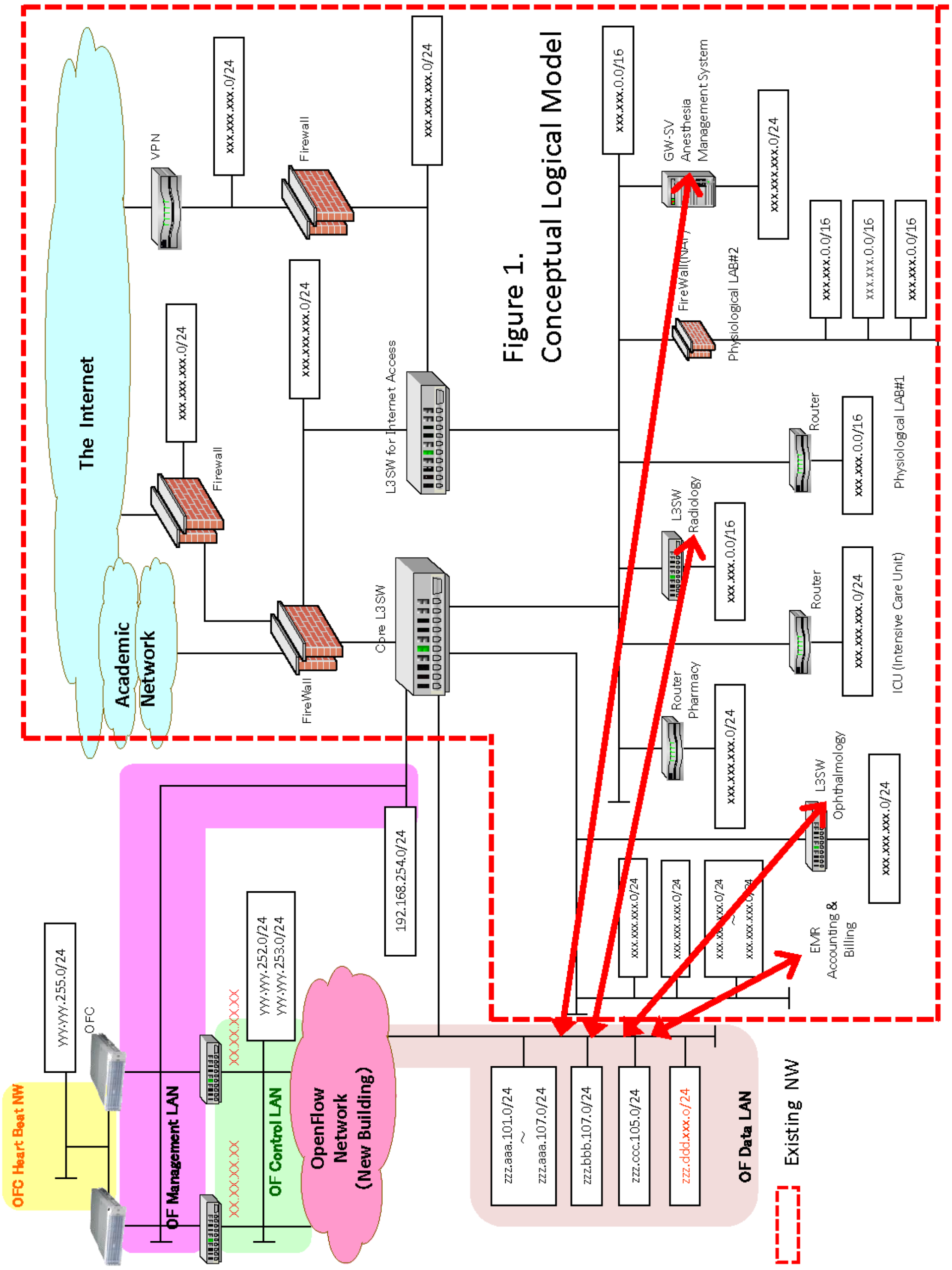


Figure 1. Conceptual Logical Model

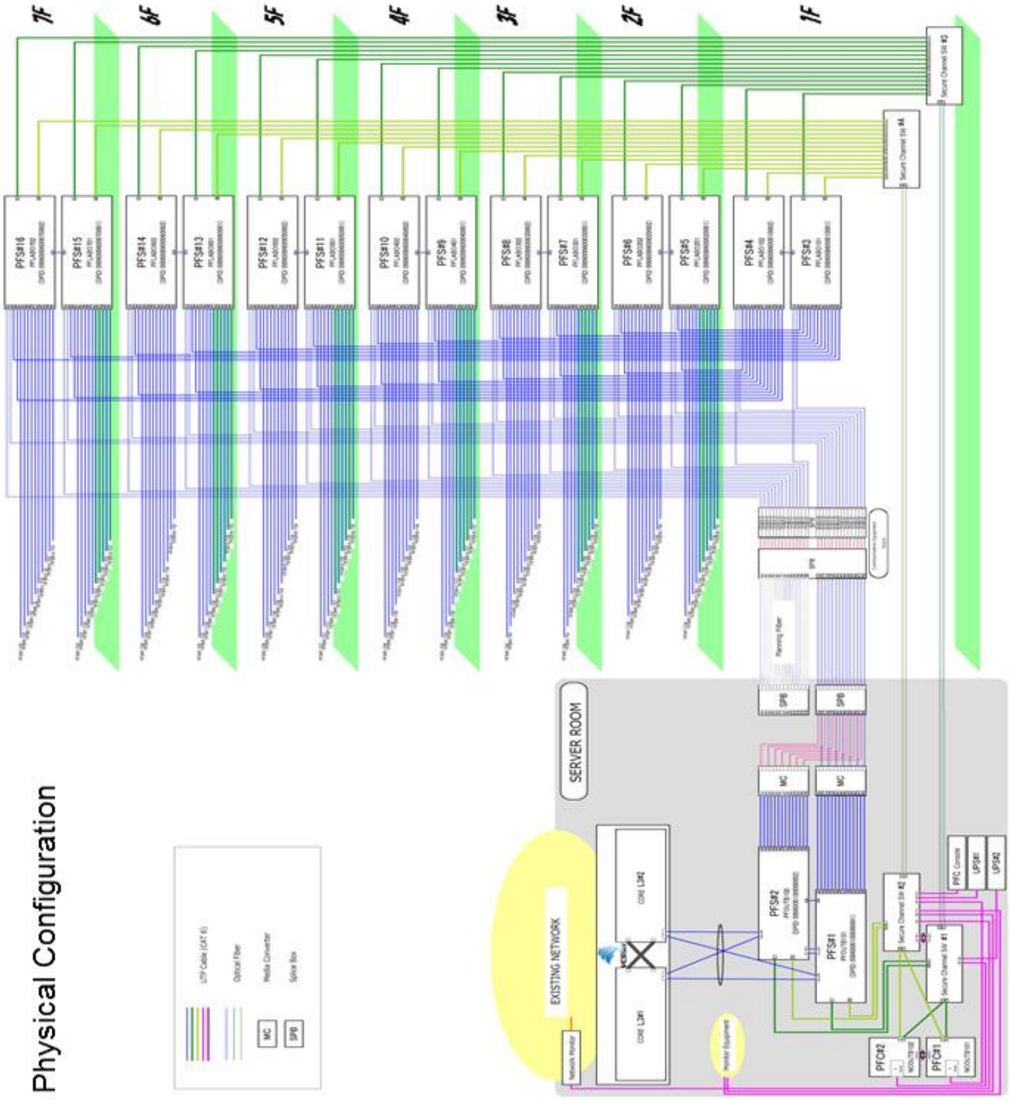
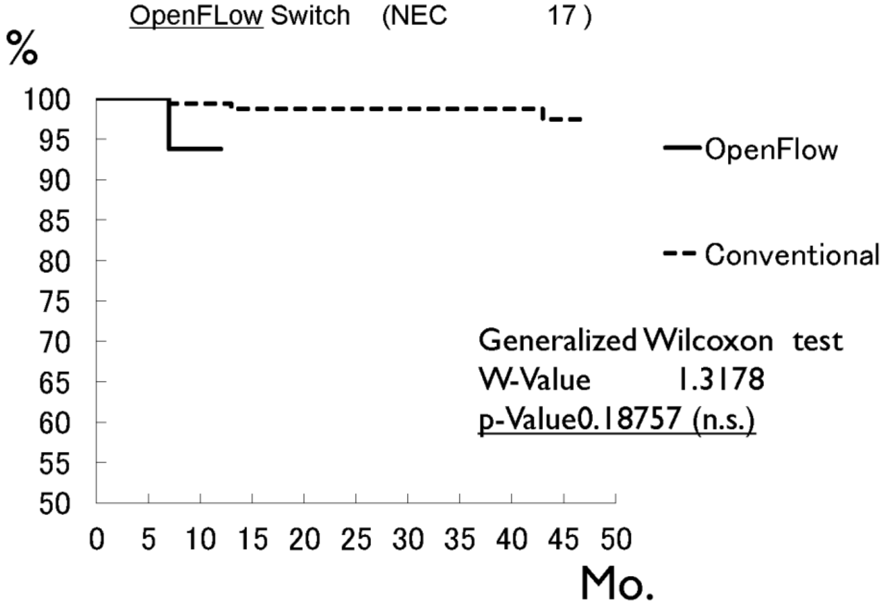


Figure 2. Physical Configuration

Figure 3 Switch Survival

Conventional Switch (Allied Telesis 158)
OpenFLow Switch (NEC 17)



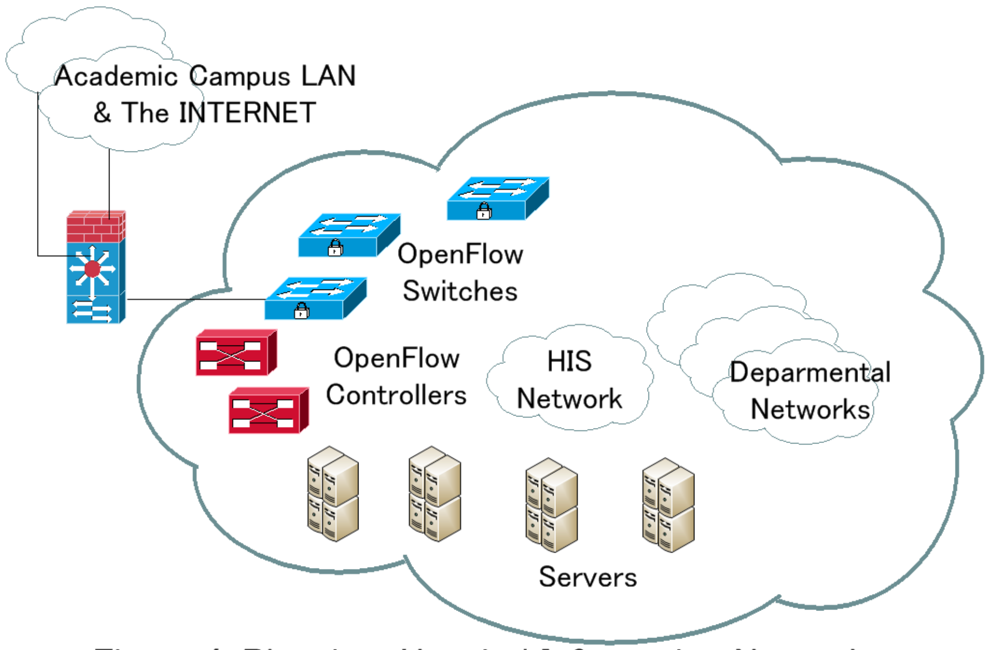


Figure 4. Planning Hospital Information Network