Proposal for a New Generation SDN-Aware Pub/Sub Environment

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***Abstract*—Software defined networks are now attracting attention from network engineers due to their flexible controllability. However, the ways in which they interact with applications, specifically, their deployment image, remains unclear. In order to investigate possible application interactions with a software defined network, attention is focused on target applications that depend on a publish and subscribe environment, with the goal of proposing a new environment that will coordinate application layer requirements and network layer services. However, since our project is still in the start-up phase, this paper will discuss the issues that will need to be resolved in order to utilize software defined network functions based on our publish and subscribe environment proposal, and our approaches to resolving them.**

Keywords-Software defined network (SDN); Publish/subscribe communication model; Overlay network; P2P middleware

I. INTRODUCTION

Recently, a number of Software Defined Network (SDN) products such as OpenFlow have been released, and work has progressed towards deploying them into productive networks [1]. SDNs provide flexible network control functions from application programs. However, it is not yet clear what kind of cross-layer control is most suitable for SDN use. Therefore, we have investigated this topic by focusing on target applications.

In this paper, the communication models used by recent Internet applications, which include Social Networking Services (SNSs) [2], groupware, streaming video, and others, will be considered. Most such applications are based on the publish and subscribe (pub/sub) communication model [3][4], which requires asynchronous message transfer and multi-source message distribution functions. Currently, since such pub/sub environments are normally only constructed as backend services for Web applications, they can only be used in data center networks. However, it is believed that if an open pub/sub environment could be provided for end-users, it could enter usage as a general-purpose middleware that provides coordination between the application and network layers. Accordingly, this study focuses on the development of an open pub/sub environment that is tightly coupled with an SDN.

Before a pub/sub environment can be directly utilized from the end-user applications, the relationship between the end user and the environment must be abstracted. In this paper, the concept "topic" is used to abstract user interests and message distribution in a pub/sub network. Once such an abstraction is provided, determining how to extract topics from user behaviors and considering the best way to optimize the resulting topic-based pub/sub network become the main targets of discussion.

However, since topic extraction alone is insufficient to control burst traffic, estimations must be performed to properly handle their impact. Here, if a drastic "topic" change can be identified, it will be referred to as a "cyberspace event". Additionally, if changes to network traffic can be traced, they will be referred to as "network events". Finally, if the "cyberspace events" are found to have correlations with the "network events", and, if future "cyberspace events" can be estimated, they can be used in advance for traffic engineering purposes.

One goal of our research is the construction of an advanced pub/sub infrastructure that weaves the user's behavior and the pub/sub network together by abstracting his or her important and/or changing interests as "topics" and "events", which include not only topic changes but also network traffic changes. Currently, since there is no strict definition for "topics", it is necessary to consider how to define and implement the term. In this paper, the issues related to this effort and our approach to resolving them will be described, in order to work towards constructing an advanced topic-based pub/sub environment that takes into consideration cyberspace and network events.

The remainder of this paper is organized as follows. In Section II, an overview structure of the proposed pub/sub environment is described and issues that must be resolved in order to establish our new pub/sub environment are outlined. Topic-based pub/sub implementation is discussed in Section III. In Section IV, ways to extract topics from user behaviors are discussed, and an approach that can be used to extract cyberspace and network events is examined in Section V. In Section VI, our related work will be shown. Finally, this paper will be concluded in Section VII.

II. PROPOSAL OVERVIEW

Fig. 1 shows an overview structure of the proposed pub/sub environment. To provide a pub/sub environment to end-users, middleware must be used to map application layer requests to network layer services. In our research, P2P Interactive Agent eXtensions (PIAX) [5], which is a peer-to-peer (P2P) middleware implementation, is employed as a pub/sub network frontend. PIAX can provide pub/sub functions via a number of different overlay networks including Skip Graph (SG) and Multi-Key Skip Graph (MKSG) [6]. In SG, any peer with a key can easily reach all the other peers that possess the same key. In MKSG, every

 ISBN: 978-1-61208-318-6

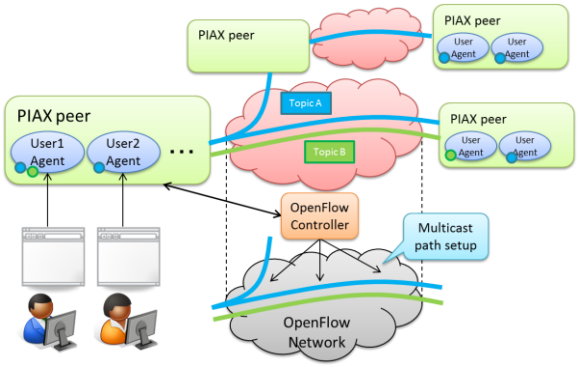

Figure 1. An overview of the proposal.

peer has the same abilities, but they can also possess multiple keys simultaneously. Thus, regarding keys as "topics" provides a straightforward approach for implementing the proposed pub/sub environment, so the base pub/sub functions are covered by using PIAX in our proposal. However, since PIAX is a P2P middleware, it does not have the ability to optimize the lower layer. Several approaches to optimize an overlay network by considering the lower layer information, such as Application Layer Traffic Optimization (ALTO) [7], and several other methods [8][9], have been researched. However, each of those approaches pose particular issues. For example, ALTO requires the addition of a special node to solve topology mismatching. In contrast, the approaches in [8] and [9] do not require special nodes, but both require complicated control and use an application level measurement method that lacks sufficient accuracy. Furthermore, they do not have a direct network equipment control function. In our approach, attempts are made to resolve these issues by integrating an SDN, specifically OpenFlow, into the pub/sub environment. The details are described in Section III.

The client side is assumed to be a Web browser or a mobile application that can access the pub/sub environment via PIAX, as shown in Fig. 1.

In order to bind a user to the user's agent, user authentication and rendezvous peer discovery are required. Here, BrowserID [10], which is an open decentralized protocol for authenticating users based on email addresses, is employed. While BrowserID is based on the low cost Public Key Infrastructure (PKI), as described in [11], if the initial authentication method and certificate duration are properly selected, it provides a good candidate for the authentication layer of our proposal. As for the rendezvous peer discovery, several approaches, such as the ones taken in Content Delivery Network (CDN) services, are available. However, if information related to the user status such as the type of network device that is currently available can be detected, it will enable the client side system to further optimize the route selection process. Thus, more investigation into the "user agent binding" issue needs to be performed, especially as related to the "topic" extraction process, as described below.

Since topic definition is not easy for end-users to perform, the user agent plays an important role in coordinating user requirements and topic-based pub/sub functions. This means that finding the most suitable way of extracting topics from each application and overlaying them into the pub/sub environment becomes a critical problem. Our current plan for resolving this problem is described in Section IV.

Topic extraction enables us to map the end-users into the network. It also gives us the opportunity to analyze any existing correlations between end-user behavior and network traffic characteristics. To investigate their applicability to traffic engineering, it is necessary to extract events from website and traffic data archives, and then to analyze the data in order to identify correlations. This process is described in detail in Section V. After extracting events, they can be utilized to control the pub/sub environment.

III. TOPIC-BASED PUB/SUB IMPLEMENTATION

As described above, topic-based pub/sub is basically provided by PIAX using MKSG and it currently does not consider the lower layer environment. Therefore, to solve topology mismatching, a lower layer information server like ALTO, or a direct control interface between the application layer and the lower layer, must be provided. In our proposal, the latter approach is adopted to minimize backend traffic.

When a user publishes a message via a pub/sub network, PIAX uses an overlay to transfer the message. If the logical path from the publisher to all the subscribers follows the graph shown at the top of Fig. 2, the message is transferred using the process shown in the bottom of the figure. In this case, since PIAX peers do not take their own physical location into consideration when generating a logical link, each message makes a round trip between the two switches. To reduce such wasteful traffic, the following two approaches can be adopted.

A. User and topic migration based on the OpenFlow information

In the case of Fig. 2, if the three users shown can be hosted on the same Personal Computer (PC), backend traffic can be reduced. Therefore, as shown in Fig. 2, (1), agent migration can reduce traffic. However, if the number of users increases, it becomes difficult to host them all on the same node. Furthermore, as described in Section II, it is important to consider rendezvous peer optimization simultaneously because the optimal peer to connect for a user device may be changed by the user agent migration. Thus, when users and topics are relocated properly based on the physical topology, the frontend and backend traffic can be reduced.

 ISBN: 978-1-61208-318-6

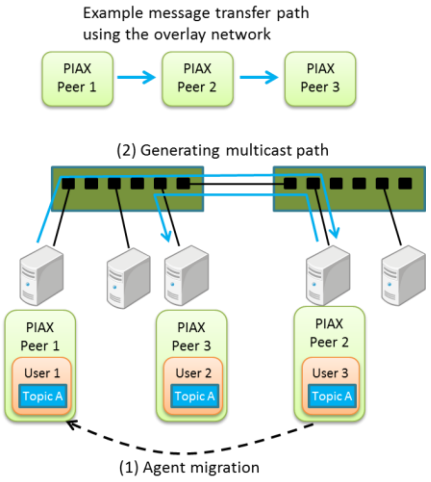

Figure 2. The possibilities to reduce backend traffic in a pub/sub network.

In the case of ALTO, the server provides lower layer information. In the case of OpenFlow, a controller node can also become an ALTO server if the lower layer status grasping function is implemented. For example, OpenFlow switch topology can be detected by using Link Layer Discovery Packets (LLDPs). This, in turn, allows PIAX to relocate user agents based on the topology information provided by the OpenFlow controller. Therefore, determining how to implement an ALTO-like function and utilizing it for user agent relocation are specific issues that need to be resolved.

B. Cross layer optimization

If user agent migration cannot be used for backend traffic reduction because it would exceed the upper limits of the node's capability, further optimization of the lower layer capability is required. For example, if a multicast path can be constructed among topic subscriber peers via OpenFlow, the total traffic will be properly reduced (Fig. 2, (2)). This requires a mapping function between the overlay network and the multicast network. An approach that can be used for constructing a multicast network in an OpenFlow network is described in [12].

IV. TOPIC EXTRACTION FROM USER BEHAVIOR

In this section, the issues related to extracting topics from user behavior are discussed. As described in Section II, the user agent must coordinate user requirements and topic-based pub/sub functions. In the pub/sub environment, entities are categorized by topics, which the user agent and client side application must translate into concepts that users can understand. Here, it is assumed that the client side is a Web browser or a mobile application, and that the Web browser functions can be extended using browser plug-ins.

For example, in our application [13], the system provides Page-Centric Communication (PCC), with which users can communicate with other users over the webpage they are

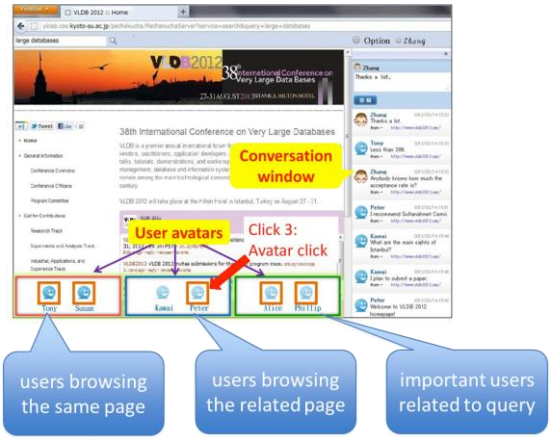

Figure 3. An example of images of page-centric communication.

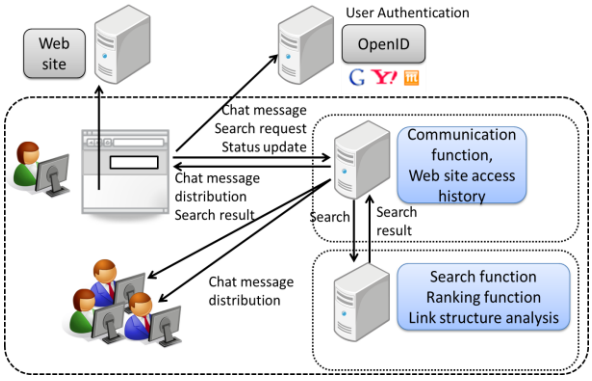

Figure 4. Current system structure of PCC.

visiting (Fig. 3). In such cases, a webpage Uniform Resource Identifier (URI) can be a pub/sub topic. Additionally, in a PCC system, a user can search for both webpages and the other users using the search function provided by the system. Thus, search keywords and webpage visit histories may help extract user interests. Fig. 4 shows the current PCC system structure. Since the current system has scalability problems, the proposed pub/sub environment may provide a solution for that issue.

Web browsers also have interfaces for obtaining user location information. These include, for example, the Geolocation Application Programming Interface (API) [14], which is currently used to attach the user location to the SNS messages. It is also used for extracting user interests. Fig. 5 shows a sample extraction approach. In this example, the correlation between a user's interest and the distance from a target location, which can also be a topic, such as Tokyo Station, is investigated.

Once a topic is extracted from a user's status, it can be mapped to the pub/sub network environment. This enables us to issue automatic topic subscriptions, which might be applicable to local disaster warning services.

Here, in the case of PCC, users can be mapped to the topics related to the webpage URI. However, if the user

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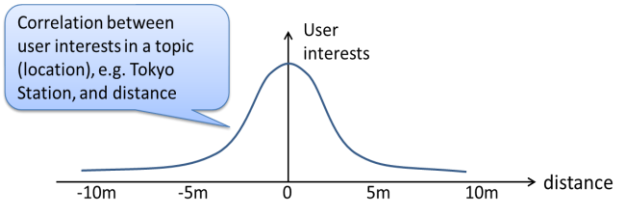

Figure 5. Correlations between user interests and distance to topics.

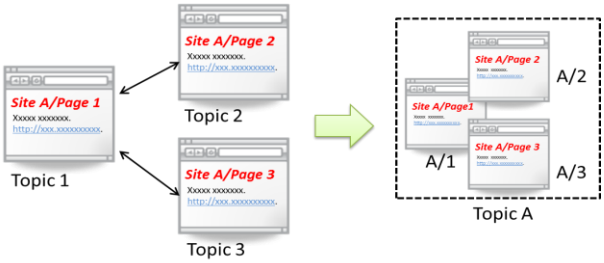

Figure 6. Topic clustering example in the Page Centric Communication System.

frequently moves among webpages, it may not be suitable to choose URIs as topics. In such cases, topic clustering may be required, as shown in Fig. 6.

As described above, topic extraction basically depends on the application specifications. To give an overview of the problem, an attempt to construct a prototype implementation and provide a framework that can be used to simplify the customization of the user agent will be described. In this example, the P2P network property defined in Web Real-Time Communication (WebRTC) [15] may be an appropriate candidate for the interface between a browser and a user agent. Interface standardization of this type would add practicality to our approach.

V. EVENT EXTRACTION

If topics related to the current user's status can be extracted, the migration of user agents and topics for topic-clustering purposes may help normal traffic reduction. However, burst traffic caused by a "cyberspace event", such as SNS messages resulting from a TV program, may exceed the allowable amount of messages per node. If the cyberspace event shows correlation to a severe traffic change (network event), and if the event can be predicted in advance, efforts can be made to prepare for the burst traffic by relocating user agents and constructing a proper multicast path.

To investigate event extraction possibilities, the correlation between the Web archive data and the traffic capture archive will be analyzed. From Web archives, especially news sites, real world and cyberspace events will be extracted, while network events can be extracted from traffic capture archives. If any correlations are identified between them, it indicates the possibility that traffic change events can be estimated in advance because news sites usually include preliminary announcements of newsworthy events.

In the Web space analysis process, the quality and credibility of the contents become important factors. In the analysis of online news archives, a simple search index mining process can be used to find terms representing fresh topics [16]. It is also possible to estimate the focus time of webpages, that is, the time periods to which the content of pages refers. Analysis methods of this type can be used for notable topics and events.

When extracting network traffic change events, existing traffic analysis methods can be used. For example, Hurst exponent analysis results of Measurement and Analysis on the Wide Internet (MAWI) [17] and Cooperative Association for Internet Data Analysis (CAIDA) [18] traffic data are being investigated as methods for detecting network events. Furthermore, it is expected that traffic estimation using time series analysis can be applicable when making minor adjustments to the event period. However, event base estimations of this type are usually difficult to apply to strict traffic control and it would be a challenging theme to implement.

VI. RELATED WORK

As previously mentioned in Section II, our proposal is very similar to ALTO. Thus, while OpenFlow controller is used as a lower layer information collector, it can also function as an ALTO server. The difference is that OpenFlow can also control the lower layer from the application layer.

Bothelho *et al.* [19] proposed the construction of a distributed OpenFlow controller that functions in a way that is very similar to our proposal from the viewpoint of integrating multiple OpenFlow networks. In our proposal, we focus primarily on the consistency and fault-tolerance of the controller while also abstracting the relationship between the application and network layers as well as the introduction of effective interactions between them.

While our proposal is also deeply related to information-centric networking and content-centric networking (ICN/CCN) [20], the most significant difference is that ICN/CCN assumes intermediate nodes have caching ability. In some applications, if the cache ability is required in our environment, it can be established at the user agent or the logically intermediate peer of the overlay network. While this is not as efficient as ICN/CCN, our approach assumes service as an intermediate node just as OpenFlow switches, thus simplifying implementation and minimizing the transfer of multicast path data. Among ICN/CCN projects, the Publish Subscribe Internet Routing Paradigm (PSIRP) [3] is more similar to our proposal. However, when our approach is compared to the PSIRP implementation, which has a high performance lower layer pub/sub environment, it was found that our approach utilizes existing methods more positively, and is simpler than PSIRP as a result. That being said,

 ISBN: 978-1-61208-318-6

usability and performance levels will need to be compared in future work.

VII. CONCLUSION AND FUTURE WORK

In this paper, a new pub/sub environment that can be used with SDNs, especially OpenFlow, was proposed and issues related to using SDN functions in the proposed environment were discussed. In our proposal, the PIAX middleware abstracts the end user's behavior and pub/sub network characteristics as "topics" and "events" to map the application layer requests to network layer services. That enables us to optimize the environment. The possibilities of network optimization in the proposed environment and several approaches that can extract the end user's behavior and network characteristics were also explored. Currently, we are developing a prototype which has a function to optimize multicast communication as discussed in section III. In the future, efforts will continue to develop and investigate the validity of our proposal from various aspects. For example, a performance evaluation of the prototype system by using "topics" and "events" extracted from existing SNSs can be a starting point.

ACKNOWLEDGMENT

This study is partially supported by the Strategic Information and Communications R&D Promotion Programme (SCOPE) and the National Institute of Informatics's joint research project. The authors would also like to express their sincere thanks to the MAWI and CAIDA project members for their assistance in this study.

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