Proactive Network Control

Hirotada Honda, Yousuke Takahashi, and Keisuke Ishibashi

Abstract

Development of virtualization technologies has enabled proactive network control and flexible resource optimization, which promise to help preempt reductions in service quality due to congestion and to increase network utilization rates. In this article, we introduce a method of traffic prediction that considers the mechanisms causing the traffic, and a means of control that is tolerant of unpredicted traffic, contributing to proactive network control.

Keywords: proactive, optimization, control

1. Introduction

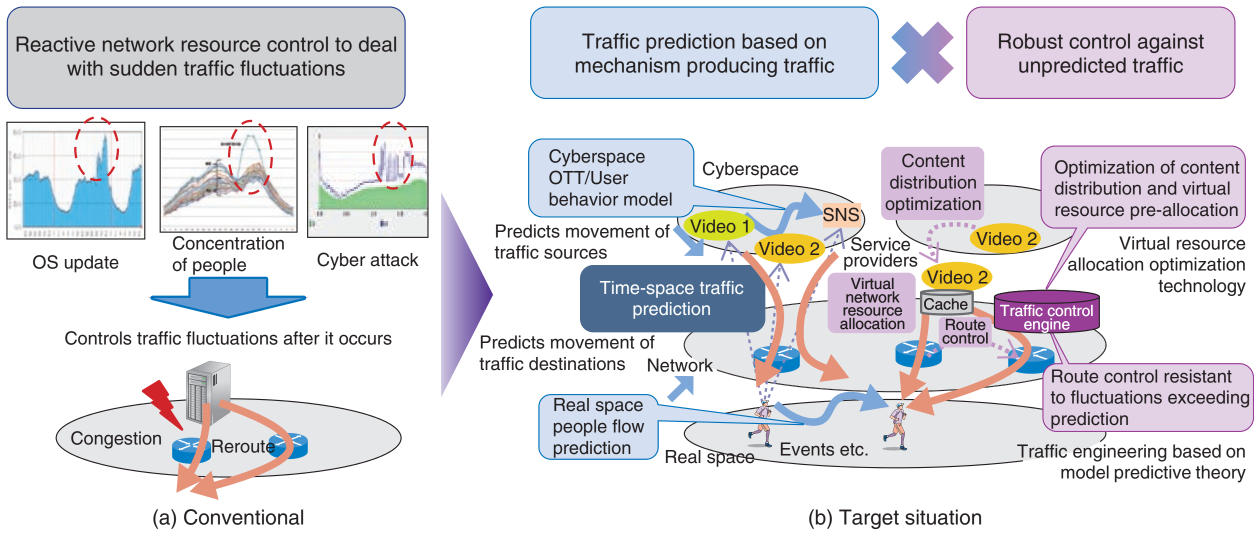
It is difficult to predict from past traffic data, sudden changes in traffic that occur due to causes such as users gathering for an event, software updates on smartphones or other mobile terminals, or changes in how services are used. Nevertheless, networks need to be able to provide stable communication even when such changes occur. Generally in the past, after sudden changes in traffic caused network congestion, a reactive control scheme was used such as diverting some or all traffic on the affected network segments to other routes. With network virtualization, resource allocation and changes can be done flexibly, so reactive control is no longer necessary, even when there are sudden changes in traffic, and proactive resource allocation schemes can now be used to achieve both maximized utilization of resources and network stability. Technology that controls network resources and traffic based on traffic prediction in this way is called *proactive network control*. We are conducting research and development on traffic prediction technologies that consider the mechanisms producing the traffic and control technologies that tolerate unpredicted traffic, toward implementing proactive network control (**Fig. 1**).

2. Traffic prediction considering mechanisms producing the traffic

Most conventional traffic prediction technologies analyze observed traffic volumes over time and make predictions by extrapolating from past data. However, it has recently become more difficult to predict traffic volumes from past observations when the factors that generate the traffic change dynamically such as when new applications or content are introduced, or when large numbers of people gather due to a special event. To predict traffic based on such traffic-generating factors, we are advancing network traffic prediction technologies that analyze the flow of human traffic in physical spaces. In particular, we are studying how to predict and control network traffic by predicting the flow of human traffic during large-scale events such as the Olympics/Paralympics, in order to avoid congestion when such events lead to people concentrating in a particular area. In the future, we intend to develop more sophisticated prediction technologies by combining this with analysis and prediction of traffic behavior in cyberspace.

3. Control that is tolerant to unpredicted traffic

There are two stages involved in handling traffic fluctuations: more accurate prediction, as discussed above, and control technology that is tolerant to unpredicted traffic. We are currently developing two



OS: operating system
OTT: over-the-top
SNS: social networking service

Fig. 1. Proactive network control.

technologies to achieve tolerance of unpredicted traffic, as described below.

- Virtual resource allocation optimization technology: Maximizes the ability to handle sudden changes in traffic and new demands from service providers by optimizing the management of idle physical resources.
- Traffic control using model predictive control technology: Classifies the predictability of traffic and applies different control policies for each classification.

We describe these control technologies below.

3.1 Virtual resource allocation optimization technology

Virtual networks need to be able to allocate resources with flexibility according to the demands of service providers. We have established a resource allocation technology that maximizes available resources based on the assumption that it is difficult to predict demand from service providers, maximizing the ability to accommodate future demand [1]. At the same time, we also minimize the reallocation of resources in order to increase quality for service providers [2]. The main strategy is that if resources on a link can be used up and there is a domain that cannot communicate without that resource, resources from other routes are allocated so as not to involve the domain in question (**Fig. 2**).

Also, if multiple routes can be selected, priority is given to unpopular routes that are only used between a limited number of domains, so that popular routes that can be used from more domains are kept available as much as possible. In the example in Fig. 2, with conventional mechanical routing, all neighboring links are used up, creating an isolated node, and resource reallocation is necessary when the next request occurs. In contrast, our proposed method uses less direct routes so that such reallocation of resources can be avoided. In the future, we will study optimization of resource allocation with network virtualization technologies, incorporating factors such as reliability, QoE (quality of experience) optimization, and minimizing power consumption, and we will work to achieve overall optimization of networks combining these multiple elements.

3.2 Traffic control using model predictive control technology

Traffic engineering is a way of actively controlling routes to accommodate more traffic using limited network resources. Conventional predictive traffic engineering technologies were developed assuming that predictions were accurate. Consequently, if the actual traffic differed largely from the predictions, ineffective routes could be selected based on the erroneous predictions. Routing was also controlled with the objective of optimizing utilization of the network

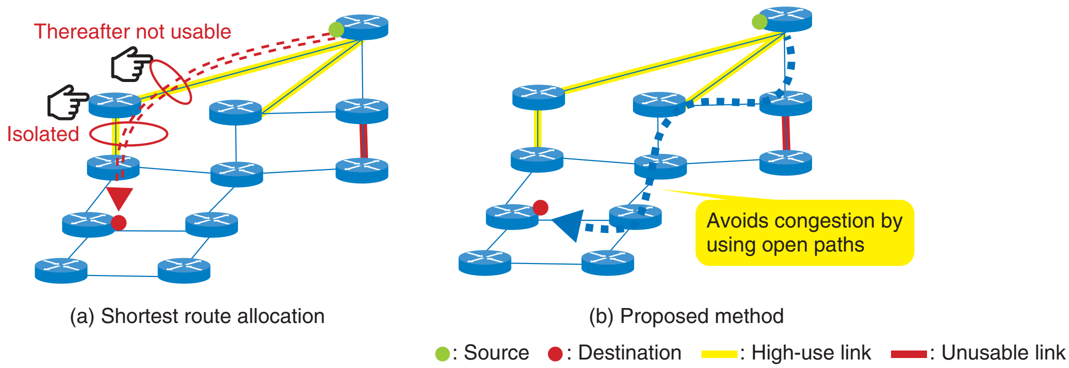
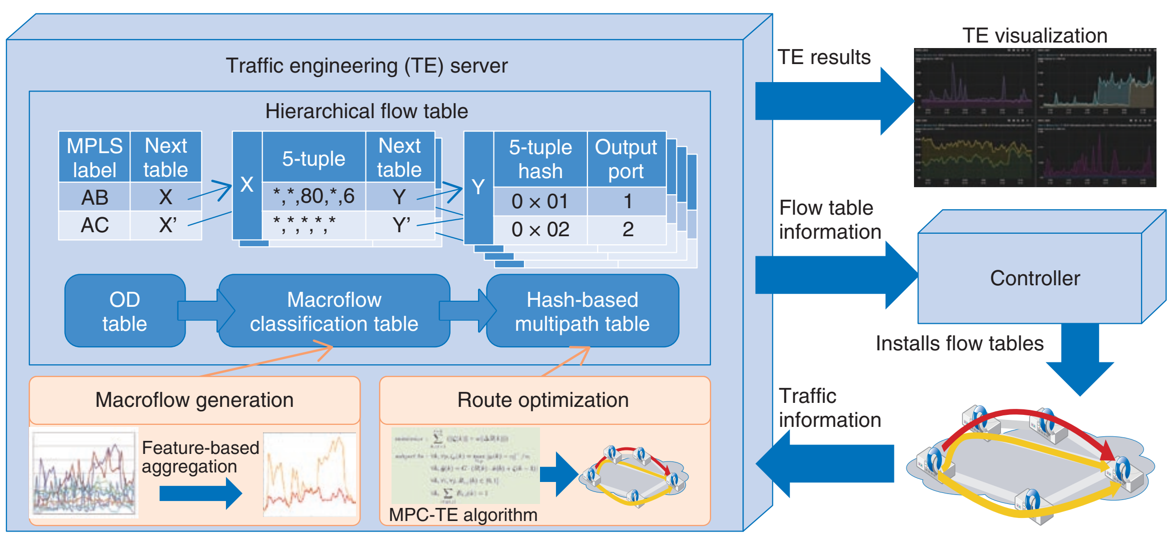


Fig. 2. Virtual resource allocation optimization technology.



MPC: model predictive control
MPLS: multiprotocol label switching
OD: origin-destination

Fig. 3. Experimental environment.

[3]; therefore, as traffic fluctuated, routes could fluctuate greatly with each control period. This could result in large changes in transmission delay with each control change, reducing communication quality.

To resolve such issues, our research group is working on traffic engineering technology that applies model predictive control, which is a type of control theory for systems that include interference that is difficult to predict. It is a practical control method that has been applied in the field of plant control. To avoid erroneous control, it represses the amount of control applied during each control cycle, approaching the target value in steps.

We applied the model predictive control idea to traffic control, avoiding erroneous control due to unpredicted traffic and implementing route control robust against prediction errors. Specifically, we formulated a new mathematical optimization problem by building model predictive control characteristics that repress the amount of route changes into the conventional problem of computing optimal routes in predictive traffic engineering. To evaluate the proposed method, we built an environment reproducing the topology, link delay, and flow data of the Internet2 test network in the USA (**Fig. 3**). The per-link

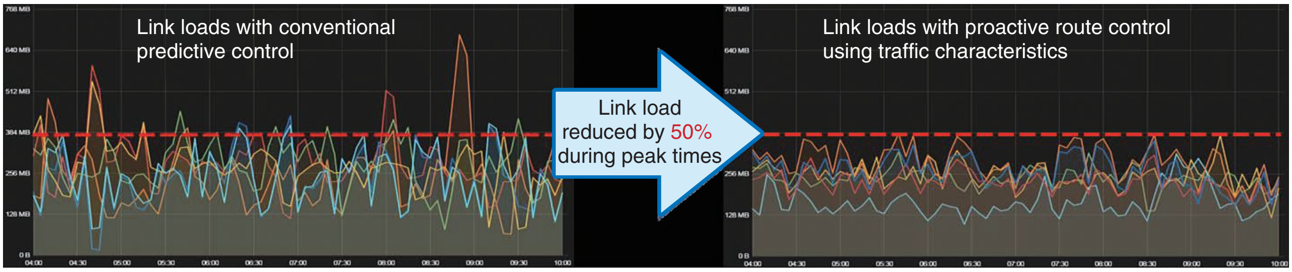


Fig. 4. Per-link traffic fluctuation.

traffic fluctuations over time for the cases using conventional predictive route control and cases using route control combined with model predictive control are shown in **Fig. 4**. With the conventional method, traffic is concentrated on specific links in several time bands, resulting in network congestion. With the proposed method, traffic spikes are distributed, reducing concentration of traffic on specific links. A comparison of maximum link loads during peak time periods confirmed that maximum link loads with the proposed method were approximately 50% of those with the conventional method.

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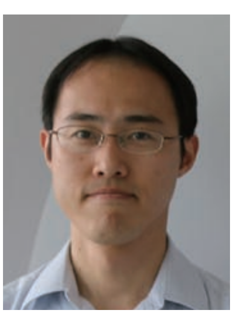

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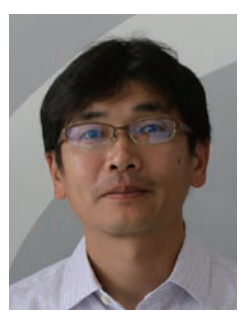

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