Resource Reservation in Information Centric Networking

Uthra Ambalavanan
uthra.ambalavanan@de.bosch.com
Robert Bosch GmbH, Bosch Research

Naresh Nayak
naresh.nayak@de.bosch.com
Robert Bosch GmbH, Bosch Research

Dennis Grewe
dennis.grewe@de.bosch.com
Robert Bosch GmbH, Bosch Research

Nitinder Mohan
mohan@in.tum.de
Technical University of Munich

ABSTRACT

Quality of Service (QoS) is a crucial mechanism where the network manages its finite resources to meet the demands promised for some applications at the cost of forsaking some other applications' needs. Information Centric Networking (ICN), although great at features such as name based addressing, decoupling host from data, in network caching, etc., still offers best effort service. This restricts the network suitability for safety critical applications such as tele-operated driving or real-time multimedia applications that often demand guaranteed bandwidth and delay. Reserving sufficient resources as well as establishing an admission control mechanism is one way to ensure performance guarantees. We present a paper emphasizing the need for a "better than best-effort service" in Named Data Networking (NDN), the functionalities to fulfil for a QoS mechanism and the open challenges in establishing resource reservation in NDN.

CCS CONCEPTS

• **Networks → Network resources allocation**; **In-network processing**; **OAM protocols**.

KEYWORDS

Resource Reservation, Quality of Service, Named Data Networking

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1 INTRODUCTION

Several safety critical applications such as tele-operated driving, connected vehicles, etc. demand guaranteed network resource provisioning with extremely low latencies. Other applications such as video conferencing request for dedicated bandwidth for smooth data delivery to users. Quality of Service (QoS) is hence, an essential attribute for such applications to function seamlessly even across limited network capacity. Information Centric Networking (ICN) architectures such as Named Data Networking (NDN) [10] is a fairly young conception, being researched over the last decade. There are still some crucial aspects in NDN, such as QoS, that are left unresolved down to the finest details.

The QoS mechanisms are often characterized by three main functions namely flow identification/classification - to distinguish the traffic that needs to be treated differently from the rest, flow specification - the QoS requirements to be met and flow treatment - specifies how the flow needs to be handled in order to meet its specifications. We discuss the design decisions and open challenges for integrating these functionalities with NDN in Section 2.

Resource reservation is an essential for achieving performance guarantees amidst dynamic traffic characteristics and resource contentions. In traditional IP networks, end-to-end resource reservation is established using the Resource reSerVation Protocol (RSVP) [11]. This protocol has many similarities to the NDN architecture, making it an intuitive first step towards an RSVP-like resource reservation in NDN. For instance, both NDN and the RSVP protocol are receiver-driven, support multicasting capabilities, store state per interest/query at the intermediate forwarders, etc. However, there are also drawbacks of RSVP for IP networks which may be retained or at times even worsened when trying to adapt RSVP-like mechanisms for NDN. We discuss on the related work focussing on resource reservation in NDN, its similarities with the RSVP protocol and the open challenges in incorporating an end-to-end resource reservation protocol for NDN in Section 3.

2 QUALITY OF SERVICE FOR NDN

In this section, we present some initial works on using the inherent features of NDN for flow identification, specification and treatment. Although there is a large scope for fine granular and expressive flow classification and specification strengthened by the name based adddressing in NDN, there are also challenges pertaining to hop-by-hop forwarding, producer-agnostic networking, and storage and management of per-interest state at the forwarders.

For flow classification, the hierarchical namespaces for naming data objects can be used for defining equivalence classes based on which the traffic is distinguished at desired prefix granularity. An initial flow classificiation specification [6] for ICN has been proposed where the intermediate forwarders recognize the prefixes from their equivalence class name type or count and handle the flows accordingly. These methods support a wide granularity of flows derived from their names which needs to be handled with the similar granularity of treatment mechanisms.

Flow specification is often consumer driven, expressed as parts of interest while the flow treatment can be a combination of both

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consumer needs of how the interest has to be handled as well as the producer's description of the nature of data mapped to the interest. The use of hierarchical namespaces widens the potential for rather expressive flow specifications. Named Function-as-a-Service (NFaaS) [5] already puts this into effect by using special keywords like "bandwidth hungry" and "delay sensitive" in names, to change the forwarding behavior of NDN forwarders. Cenk Gündoğan et. al. [3] define `reliable`, `prompt` and `regular` keywords to mark flows in order to be treated differently. While flows marked with `prompt` are latency conscious, flows marked with `reliable` ensure reliable data delivery. Expressive flow specifications demand diverse treatment mechanisms as well which challenges the processing and memory management at the forwarders degrading their performance and speed. This limits the number of different QoS specifications that can be supported. [4] suggests having a hierarchy of QoS specification for easier handling.

The flow treatments can be established by manipulating the resources at forwarders such as Content Store (CS), Pending Interest Table (PIT) and Forwarding Information Base (FIB) and the link capacity. For example, consumers can manipulate the forwarding behavior by specifing the forwarding strategy to use for an interest or enable special caching strategies for different classes of flows. Cenk Gündoğan et. al. [3] suggest prioritized forwarding, priority-based cache replacement decisions and PIT management to enable rapid forwarding of priority traffic as QoS treatment mechanisms incorporated at every router. For instance, [1] presented flow treatments by treating data based on its popularity and determine the cache placement of such data in one of three placements namely locally cached, remotely cached and uncached data in CCN networks. [4] gives an overview of the different methods of incorporating QoS treatments.

3 RESOURCE RESERVATION FOR NDN

Reserving sufficient resources along with an admission control mechanism to map the reserved resources to the flow is one way to ensure performance guarantees. Although there are contributions towards favourable design decisions for QoS [7], and some early resource reservation concepts for NDN, they often do not address all functionalities of a QoS mechanism in an efficient manner.

The decentralized RSVP [11] protocol used in IP networks, is a receiver driven protocol, where the reciever initiates the `resv` message. The `resv` message traverses across the intermediate routers until it reaches the sender. The sender then sets up appropriate control parameters and sends the `path` message. The `path` message contains information about the nature of the data, along with the path information appended at each router for the upcoming request to follow. If the requested resources cannot be allocated for the flow, the `resv` message is responded with a negative acknowledgement.

RSVP in IP has its similarities with NDN. RSVP follows a request/response mechanism, similar to the interest/data flow in NDN. Similar to NDN, the receivers in RSVP are notified of the status of reservation request with an acknowledgement in their response. Both NDN and RSVP requires storage of state at the forwarders on path to the producer. Due to these aspects, adapting RSVP-like mechanisms for NDN seems a straight forward solution.

Tian Pan et. al. [8] offer an SDN-based centralized approach for optimal cache reservation to provide deterministic latency guarantees. Traditional IP networks use decentralized approach where the end-to-end resource allocation could be inefficient due to lack of globally optimal resource reservations. Establishing resource reservation in NDN using SDN-like centralized approach for mapping the requests with resources has serious scalability issues as the controller has to perform per-flow, per-hop, per-consumer decisions.

SCARI [9] is a strategic caching and reservation for ICN that follows RSVP-like mechanisms to reserve bandwidth and cache end-to-end. It uses data prefixes for both flow identification and specification while the flow treatment is done by manipulating the content store at forwarding routers and reserving bandhwidth. However, it does not address admission control mechanism for consumers of data. Adaptive bandwidth reservation [2] follows a similar mechanism for reserving bandwidth for CCN. Such solutions reserve resources for the data instead of the consumer. There is also a need for a strategy to identify and mitigate wasteful reservation of resources by spurious consumers.

The very advantage that NDN provides for expressive QoS specification is also a disadvantage when mapping infinite options of namespaces to finite set of resources. More flexible and general the specification is, more strain is added to the routers to meet these requirements. As queues and priority levels increase, the expenses to reserve dedicated CS, PIT and FIB resources rises.

RSVP protocol in IP already has scalability concerns owing to the storage of per-flow state in the network rendering it suitable mostly for only private small scale networks. This worsens with NDN as it needs to store and manage state on a per-topic, per-interest and per-consumer basis as well as process the control messages further degrading the forwarding performance. Resources reserved for only long as interest lifetime alleviates the scalability issues to an extent. Due to the hop-by-hop producer agnostic forwarding in NDN, providing an end-to-end dedicated resources along with admission control segregating the consumers who requested reservation from those who didn't, are open challenges to be addressed.

4 CONCLUSION

Several applications demand certain guarantee of operation from the network. NDN, an ICN based network architecture, offers best effort service. Establishing QoS mechanisms is essential for NDN to be widely adopted. In this paper, we present the building blocks of QoS mechanisms, discuss the merits and demerits of the NDN architecture's inherent features for adopting QoS, and as a first step on the analysis of the suitability of an RSVP-like resource reservation for NDN. We see that although, RSVP appears to be a promising integration to NDN, there are still some drawbacks that needs to be solved with priority.

REFERENCES

[1] Weibo Chu, Lifang Wang, Haiyong Xie, Zhi-Li Zhang, and Zejun Jiang. 2016. Network delay guarantee for differentiated services in content-centric networking. *Computer Communications* 76 (2016), 54–66. https://doi.org/10.1016/j.comcom.2015.09.009

[2] Tomoharu Endo, Atsuko Yokotani, Satoshi Ohzahata, Ryo Yamamoto, and Toshihiko Kato. 2018. An Adaptive Bandwidth Reservation Method for a Content-Centric Network. In *2018 IEEE 42nd Annual Computer Software and Applications Conference (COMPSAC).*

[3] Cenk Gündoğan, Jakob Pfender, Michael Frey, Thomas C. Schmidt, Felix Shzu-Juraschek, and Matthias Wählisch. 2019. Gain More for Less: The Surprising Benefits of QoS Management in Constrained NDN Networks. In *Proceedings of the 6th ACM Conference on Information-Centric Networking (ICN '19)*. Association for Computing Machinery, New York, NY, USA, 141âĂŞ152. https://doi.org/10.1145/3357150.3357404

[4] Anil Jangam, Prakash Suthar, and Milan Stolic. 2020. *QoS Treatments in ICN using Disaggregated Name Components*. Internet-Draft draft-anilj-icnrg-dnc-qos-icn-02. Internet Engineering Task Force. https://datatracker.ietf.org/doc/draft-anilj-icnrg-dnc-qos-icn/02/ Work in Progress.

[5] Michał Król and Ioannis Psaras. 2017. NFaaS: Named Function as a Service. In *Proceedings of the 4th ACM Conference on Information-Centric Networking (ICN '17)*. Association for Computing Machinery, New York, NY, USA. https://doi.org/10.1145/3125719.3125727

[6] Ilya Moiseenko and David R. Oran. [n.d.]. *Flow Classification in Information Centric Networking*. Internet-Draft draft-moiseenko-icnrg-flowclass-07. Internet Engineering Task Force. https://datatracker.ietf.org/doc/draft-moiseenko-icnrg-flowclass/07/

[7] David R. Oran. 2021. Considerations in the Development of a QoS Architecture for CCNx-Like Information-Centric Networking Protocols. RFC 9064. https://www.rfc-editor.org/info/rfc9064

[8] Tian Pan, Cheng Xu, Jianhui Lv, Qianqian Shi, Qing Li, Chenhao Jia, Tao Huang, and Xingchen Lin. 2019. LD-ICN: Towards Latency Deterministic Information-Centric Networking. In *2019 IEEE 21st International Conference on High Performance Computing and Communications; IEEE 17th International Conference on Smart City; IEEE 5th International Conference on Data Science and Systems (HPCC/SmartCity/DSS)*. 973–980. https://doi.org/10.1109/HPCC/SmartCity/DSS.2019.00140

[9] Susmit Shannigrahi, Chengyu Fan, and Christos Papadopoulos. 2018. SCARI: A Strategic Caching and Reservation Protocol for ICN *(ICN '18)*. Association for Computing Machinery. https://doi.org/10.1145/3267955.3269021

[10] Lixia Zhang, Alexander Afanasyev, Jeffrey Burke, Van Jacobson, KC Claffy, Patrick Crowley, Christos Papadopoulos, Lan Wang, and Beichuan Zhang. 2014. Named data networking. *ACM SIGCOMM Computer Communication Review* 44, 3 (2014), 66–73.

[11] L. Zhang, S. Deering, D. Estrin, S. Shenker, and D. Zappala. 1993. RSVP: a new resource ReSerVation Protocol. *IEEE Network* (1993). https://doi.org/10.1109/65.238150