LPECN: Leveraging PIT placement and Explicit marking for Congestion control in NDN

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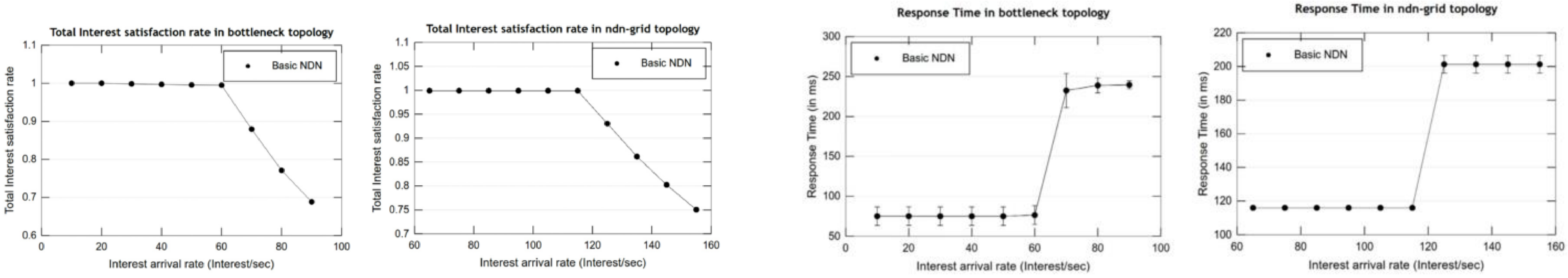
Outline

- Motivation behind our proposed work
- Contributions
- Design rationale of considering PIT per outgoing face placement
- Proposed Scheme
- Performance Analysis
- Conclusion and future Work

Motivation behind our proposed work

- Pending Interest Table (PIT) should have a finite size [1]. If the outgoing links do not have enough capacity
- to handle traffic, it will result in increasing outgoing queue size. This affects the low latency needs of real-time applications.



(a) (b) (c) (d)

Figure 1 : Interest Statisfaction Rate and Response Time for 6-node bottleneck and 9-node ndn-grid topology w.r.t. Interest Arrival Rate (considering infinite PIT size) [results are taken from [2]]

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[1] Madhurima Buragohain, Prashant Gudipudi, Md Zaki Anwer, and Sukumar Nandi. 2019. EQPR: enhancing QoS in named data networking using priority and RTT driven PIT replacement policy. In ICC 2019-2019 IEEE International Conference on Communications (ICC). IEEE, 1–7.

[2] Madhurima Buragohain and Sukumar Nandi. 2020. Quality of Service provisioning in Named Data Networking via PIT entry reservation and PIT replacement policy. Computer Communications 155 (2020), 166–183

Motivation behind our proposed work

- Due to presence of bursty traffic or any non-responsive consumer, PIT may became full and subsequent packets will be dropped. This causes a significant interest sending rate reduction for responsive consumers due to reduction of consumer window.

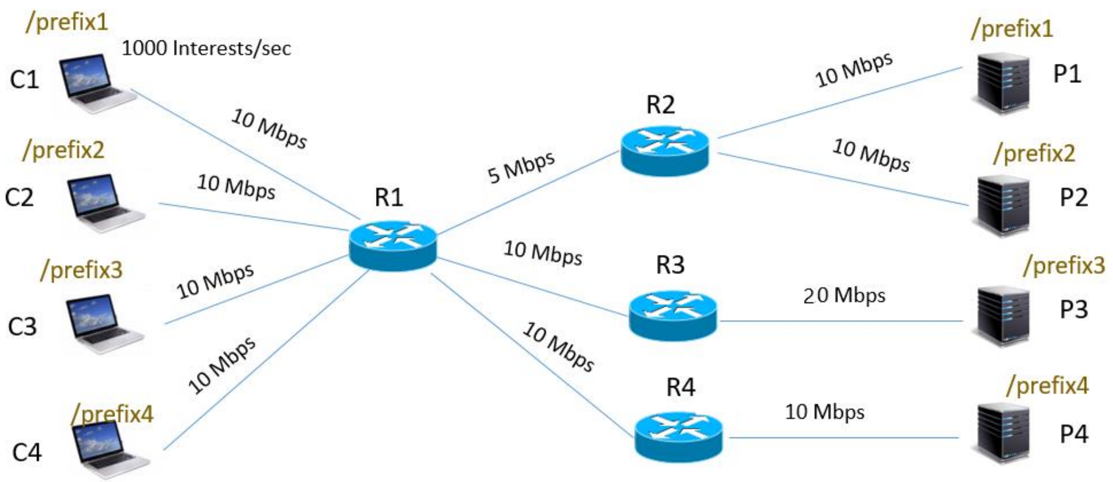
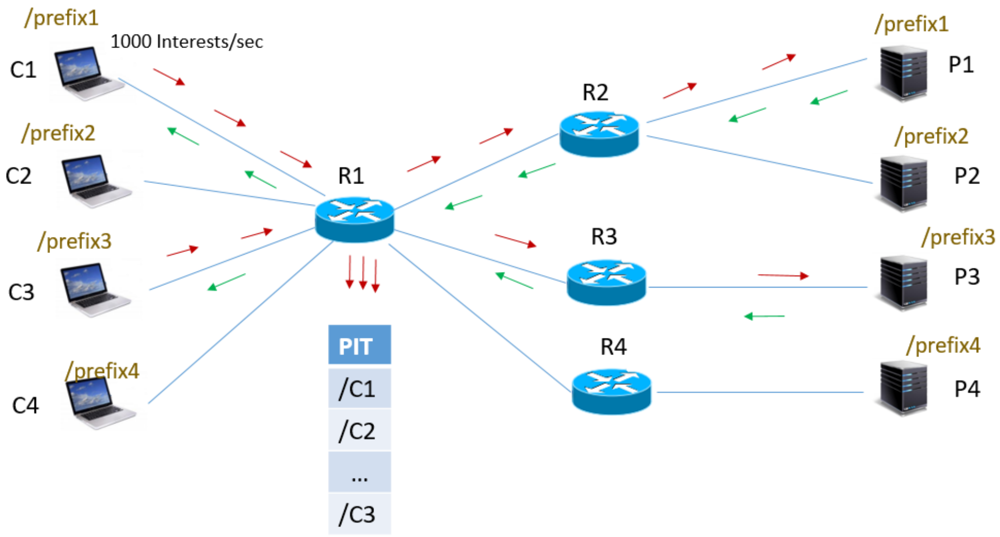


Figure 2 : Topology



PIT
/C1
/C2
…
/C3

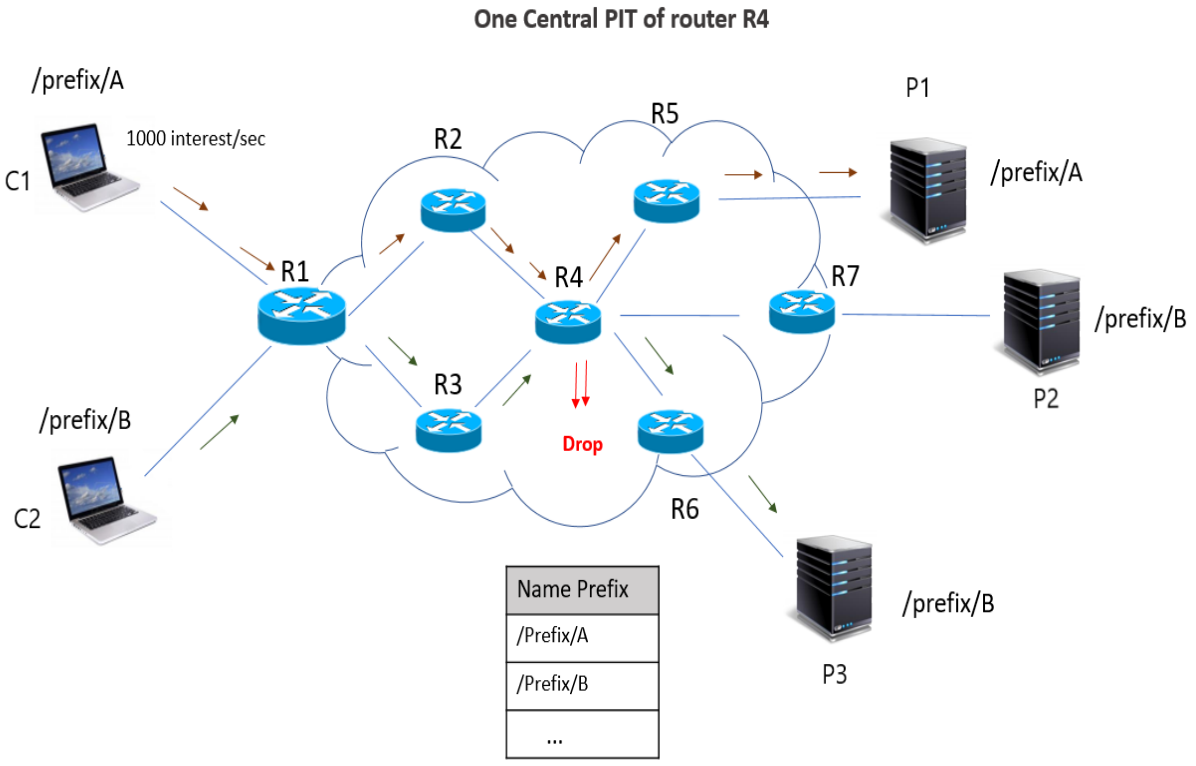
Figure 3 : Packets are dropped at R1 (PIT Full)

Contributions

- We have used PIT per outgoing face placement to efficiently limit the Interest sending rate according to the available capacity of the link, which can avoid congestion in the reverse path.
- We have used queuing delay and PIT occupancy for congestion detection. We mark data packets and use NACK for congestion signalling.
- We make use of NACK and explicit marking to detect and limit Interests from non-responsive consumers. This is possible due to NDN’s architectural properties such as symmetric forwarding and stateful forwarding plane.
- We have implemented our proposed scheme LPECN in ndnSIM simulator. From the simulation result, we have observed that our proposed scheme can handle congestion even in the presence of non-responsive consumers.

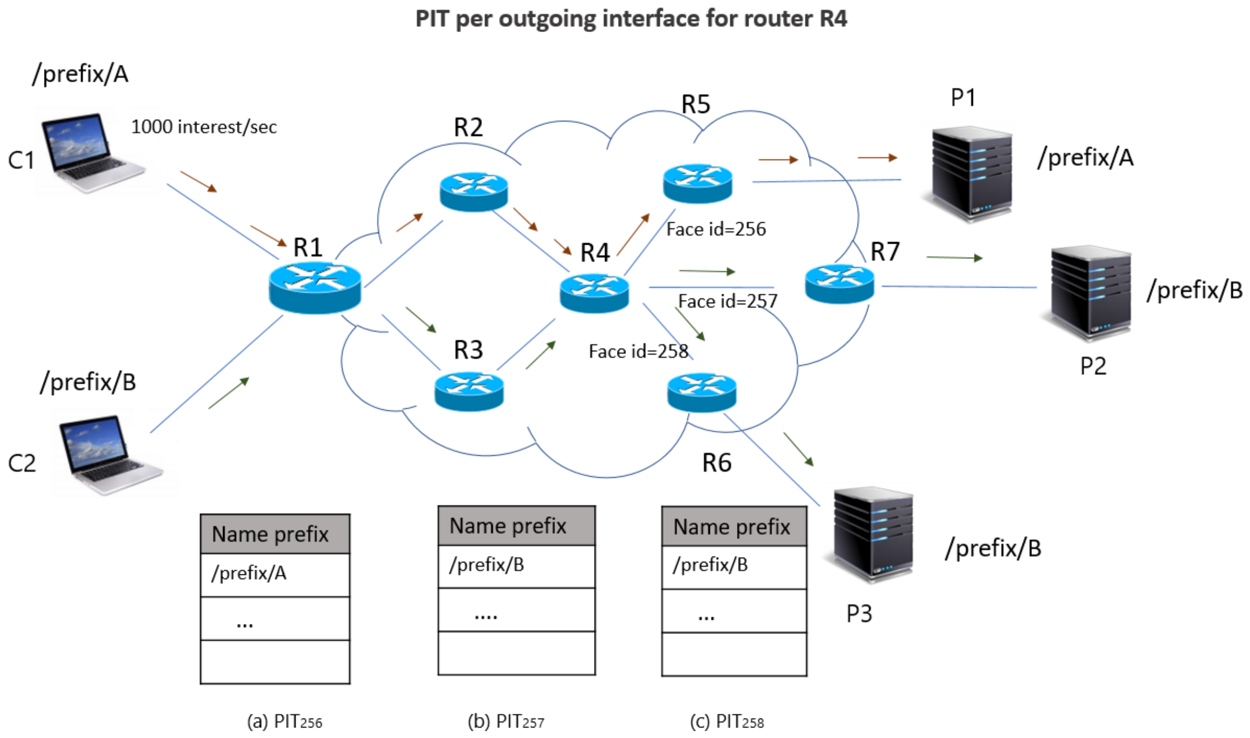
Please note that LPECN only works with best-route forwarding, and if more flexible forwarding is needed, some other PIT design is more appropriate.

Motivation behind consideration of PIT per outgoing face placement


One Central PIT of router R4

Name Prefix
/Prefix/A
/Prefix/B
...

Figure 4 : Central PIT


PIT per outgoing interface for router R4

Name prefix
/prefix/A
...

(a) PIT_{256}

Name prefix
/prefix/B
....

(b) PIT_{257}

Name prefix
/prefix/B
...

(c) PIT_{258}

Figure 5 : Distributed PIT

Motivation behind consideration of PIT per outgoing face placement

- **Estimation of PIT size**:

$$PS = [BW/(l_I + l_I * k * \rho] * [(\tau - \delta_{rtt}) * (1 - \rho) + \delta_{rtt}] \qquad (1)$$

Where
PS = PIT size,
BW = Bandwidth of the outgoing link,
l_I = Average interest packet size,
k = Ratio between Data and Interest packet sizes,
ρ = Ratio of well behaved Interest traffic,
τ = PIT entry timeout (default value: 4sec),
δrtt = Average round trip time.

We adopt equation (1) from [3]

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[3] Aytac Azgin, Ravishankar Ravindran, and Guoqiang Wang. 2016. pit/less: Stateless forwarding in content centric networks. In 2016 IEEE Global Communications Conference (GLOBECOM). IEEE, 1–7.

Proposed Scheme (LPECN)

1. Congestion detection and signalling
2. Adaption of consumer window
3. Forceful Interest rate limitation

Congestion detection and Signalling

- Congestion detection is done by monitoring both PIT size and queuing delay[4].
- Congestion signalling is done via marking outgoing data packet and sending NACK packets .

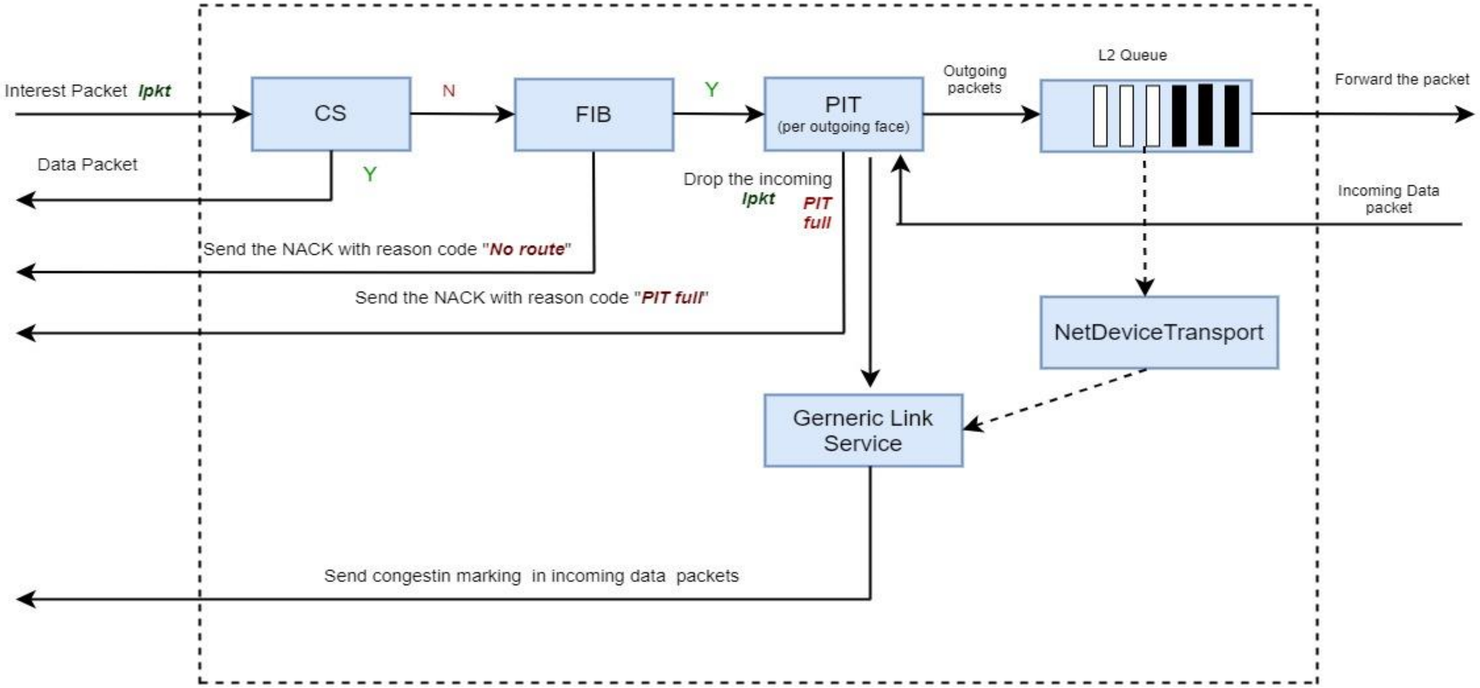


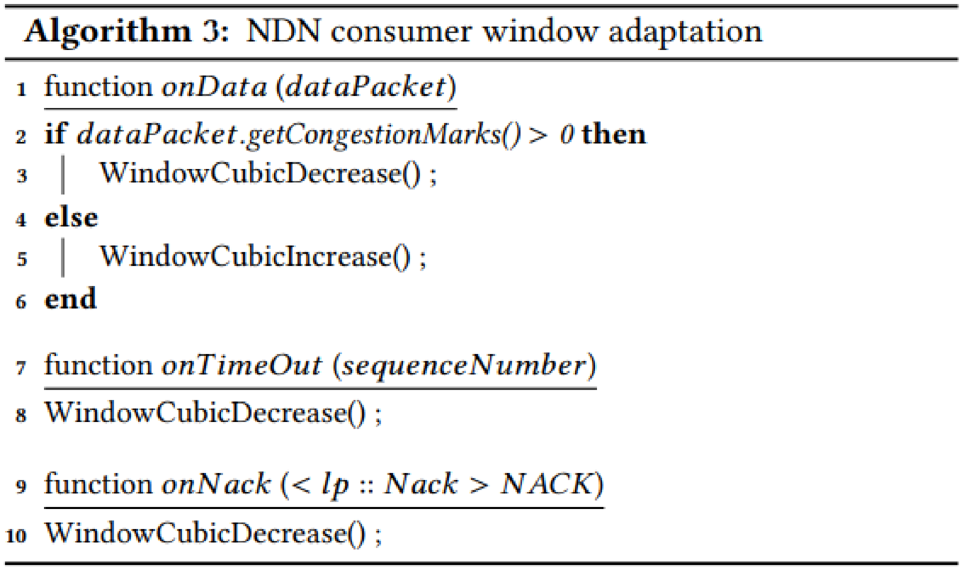
Figure 6 : Congestion detection and Signalling in LPECN

Please refer to Algorithm 1 in our paper for implementation of Packet forwarding in PIT per outgoing face placement in NFD and Algorithm 2 for detection of congestion detection and signalling

[4] Kathleen Nichols, Van Jacobson, Andrew McGregor, and Jana Iyengar. 2018. Controlled delay active queue management. RFC 8289 1 (2018), 1–25.

Adaptation of consumer window

- We adopt CUBIC congestion control [3] at consumer side due to its stability and scalability over fast and long-distance networks.



Algorithm 3: NDN consumer window adaptation

```
function onData (dataPacket)
if dataPacket.getCongestionMarks() > 0 then
    WindowCubicDecrease() ;
else
    WindowCubicIncrease() ;
end
function onTimeOut (sequenceNumber)
WindowCubicDecrease() ;
function onNack (< lp :: Nack > NACK)
WindowCubicDecrease() ;
```

WindowCubicIncrease() and WindowCubicDecrease() in Algorithm 3 are considered directly from CUBIC. The source code is available in the ndnSIM simulator (version 2.8)

[5] Sangtae Ha, Injong Rhee, and Lisong Xu. 2008. CUBIC: a new TCP-friendly high-speed TCP variant. ACM SIGOPS operating systems review 42, 5 (2008), 64–74.

Forceful Interest Rate limitation

- After receiving a NACK or congestion marking, Consumer side edge router observes the interest rate per time interval to infer whether a consumer reduces the Interest rate or not. If it finds any consumer which does not reduce the rate, it limits the interest by limiting the PIT size for that consumer.

Please refer to Algorithm 4 for more details

Performance Analysis

☐ We implement LPECN in C++ over ndnSIM simulator (version 2.8). To evaluate the effectiveness of our proposed scheme, we compare it against PCON [6].

Performance Metrics:

- **Average Goodput**: Average number of data packets per unit time received by consumers.
- **Average Response Time**: Average time required by consumers to bring the data back.
- **Average Interest Satisfaction Rate**: It is the ratio of the total data packets received by the consumers to the total Interest packets forwarded

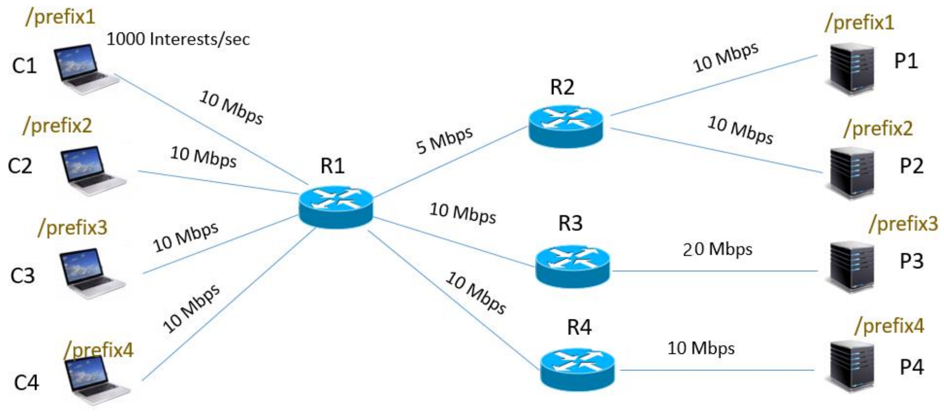
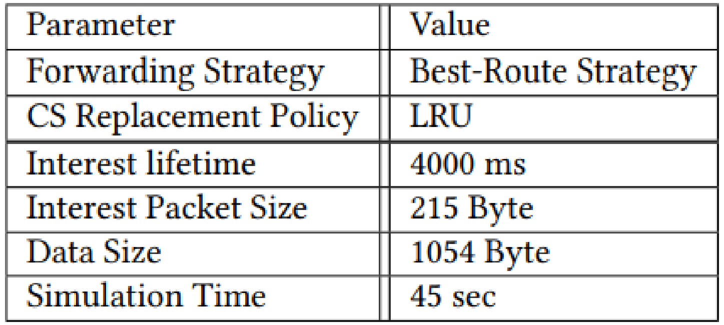


Figure 7: Topology 1

Table 1: SIMULATION PARAMETERS



Parameter	Value
Forwarding Strategy	Best-Route Strategy
CS Replacement Policy	LRU
Interest lifetime	4000 ms
Interest Packet Size	215 Byte
Data Size	1054 Byte
Simulation Time	45 sec

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[6] Klaus Schneider, Cheng Yi, Beichuan Zhang, and Lixia Zhang. 2016. A practical congestion control scheme for named data networking. In Proceedings of the 3rd ACM Conference on Information-Centric Networking. 21–30

Performance Analysis

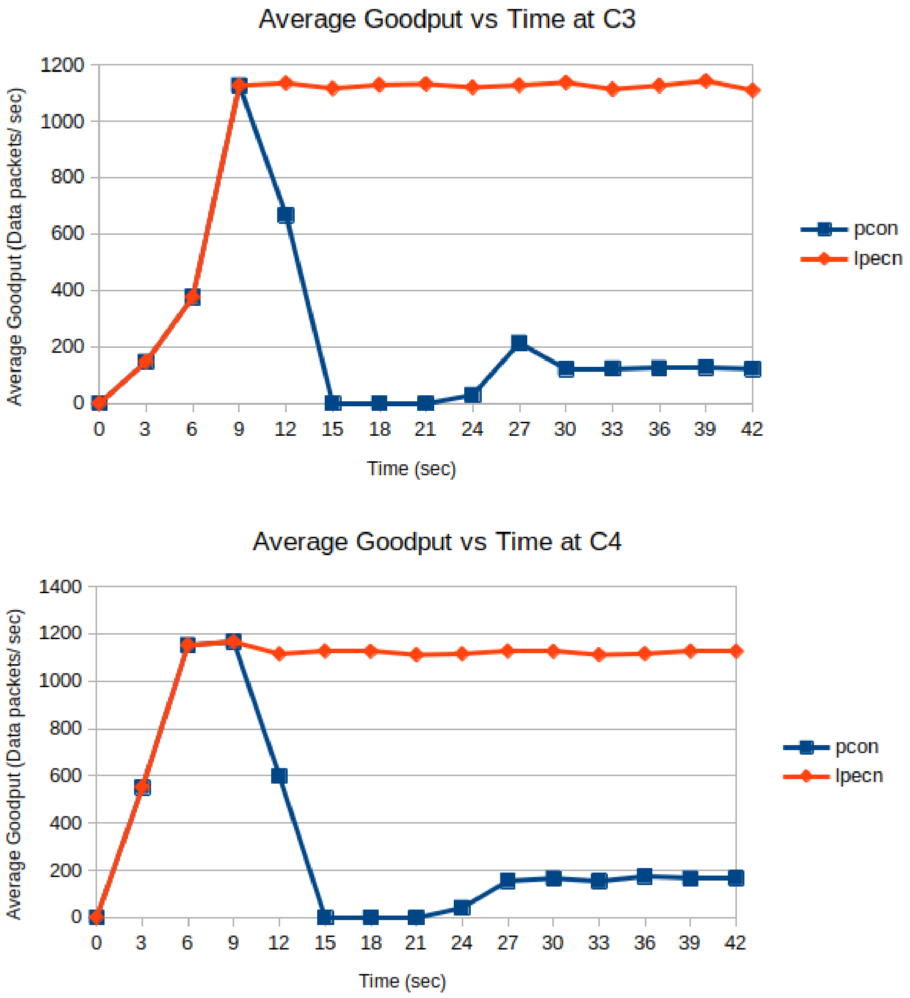


Figure 8: Average Goodput at consumer C3 and C4 in PCON and LPECN scheme

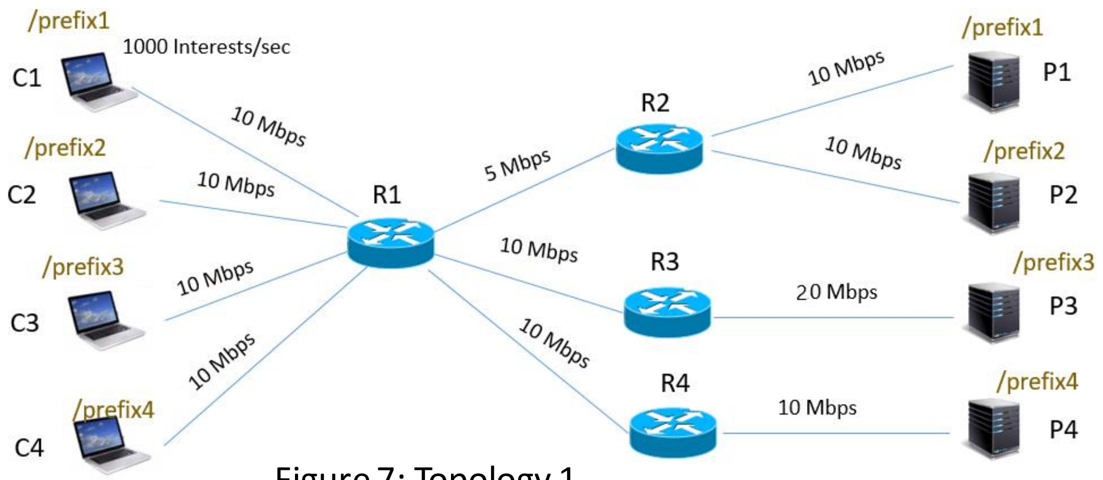


Figure 7: Topology 1.

(C1 sends a traffic burst of 1000 Interests/sec, and it does not respond to any congestion signal. Consumers C2, C3 and C4 start sending Interests at t=1 sec and stop at t=42 sec. Consumer C1 starts t=10 sec and stops at t=42 sec)

Performance Analysis

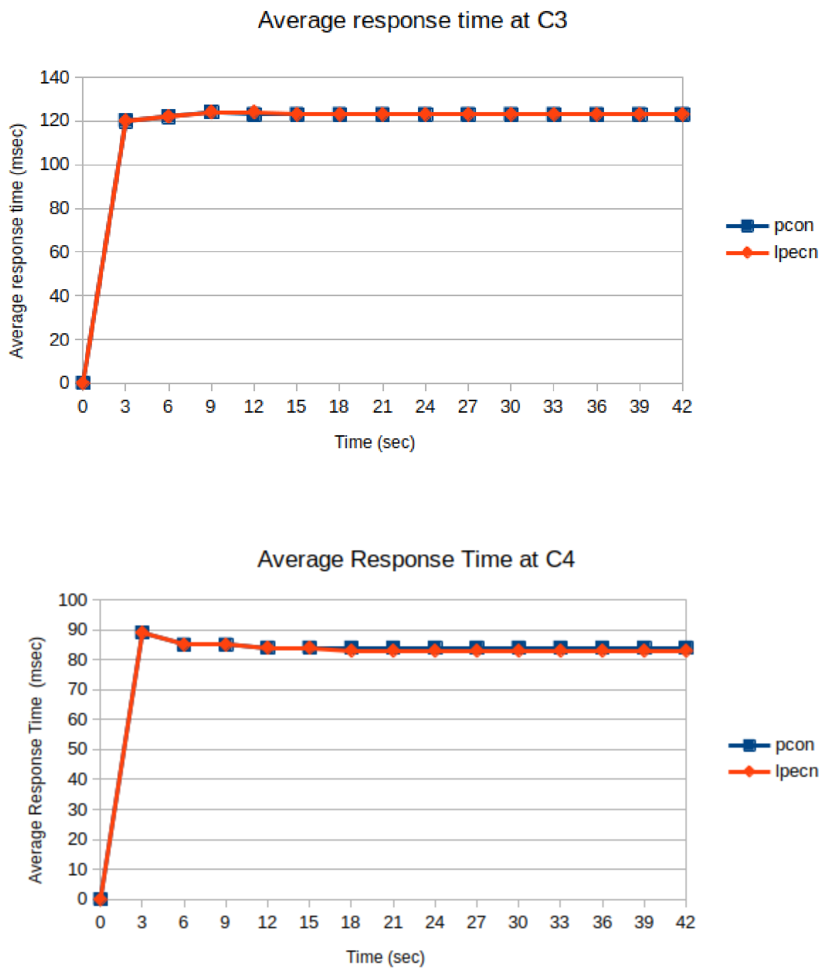


Figure 9: Average Response time at consumer C3 and C4 in PCON and LPECN scheme

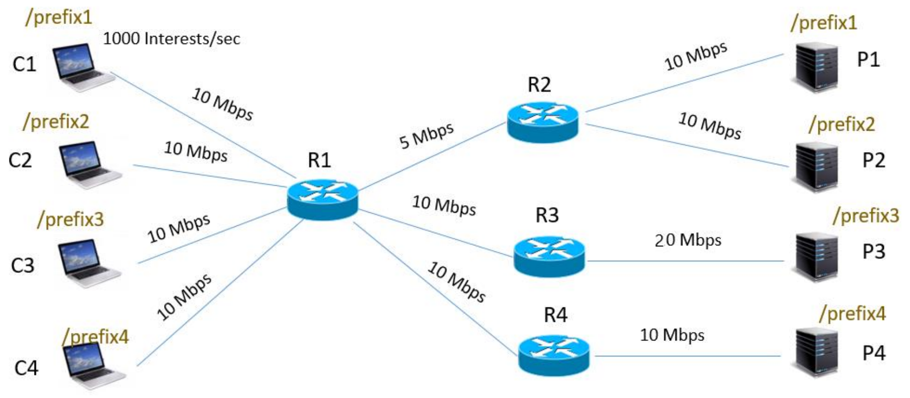


Figure 8: Topology 1.

(C1 sends a traffic burst of 1000 Interests/sec, and it does not respond to any congestion signal. Consumers C2, C3 and C4 start sending Interests at t=1 sec and stop at t=42 sec. Consumer C1 starts t=10 sec and stops at t=42 sec)

Performance Analysis

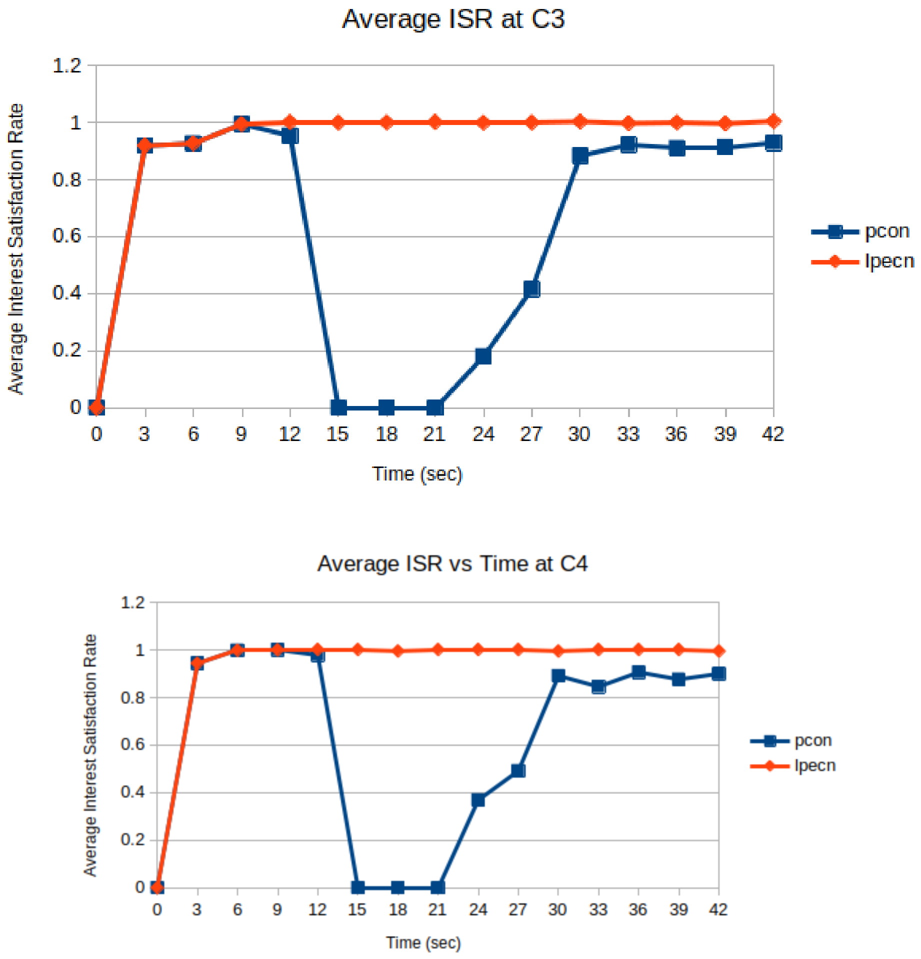
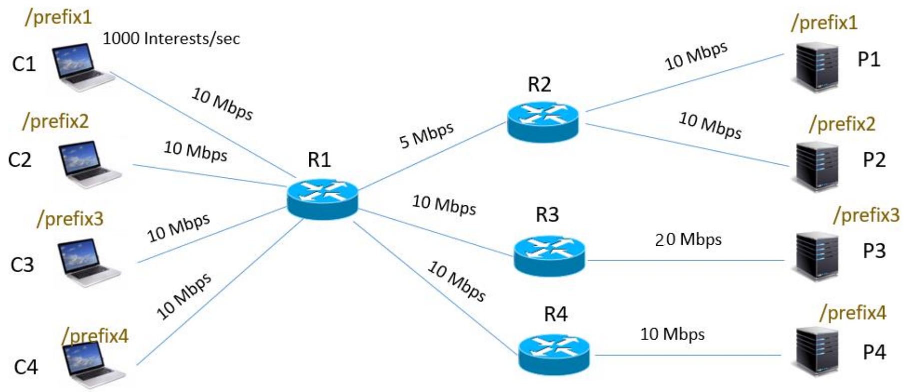


Figure 10: Average Interest satisfaction Rate at consumer C3 and C4 in PCON and LPECN scheme



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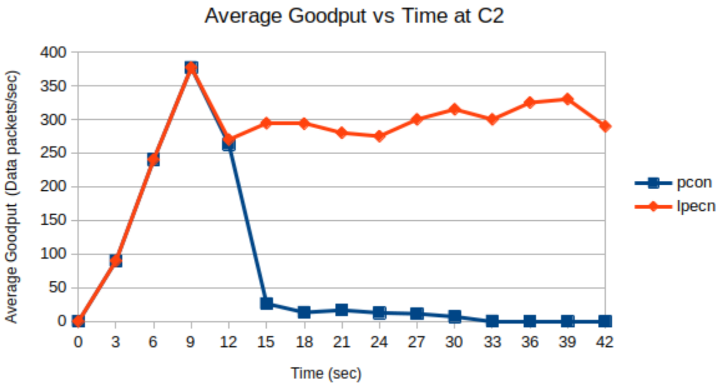
Performance Analysis


Average Goodput vs Time at C2

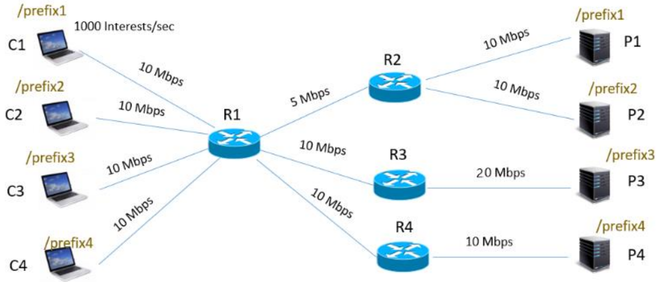
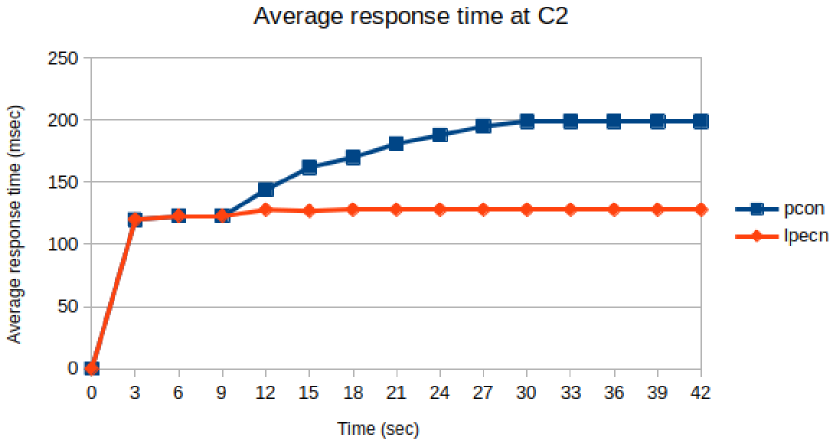


Figure 8: Topology 1


Average response time at C2

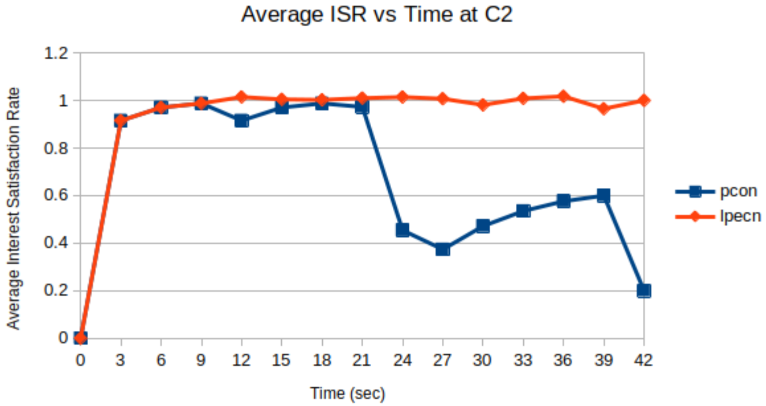
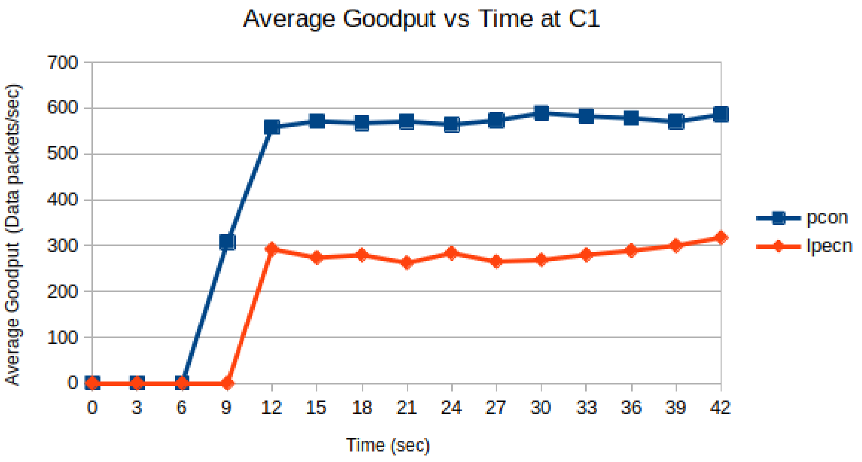

Average ISR vs Time at C2

Figure 11: Average Goodput, Response Time and ISR at consumer C2 in PCON and LPECN scheme

Performance Analysis



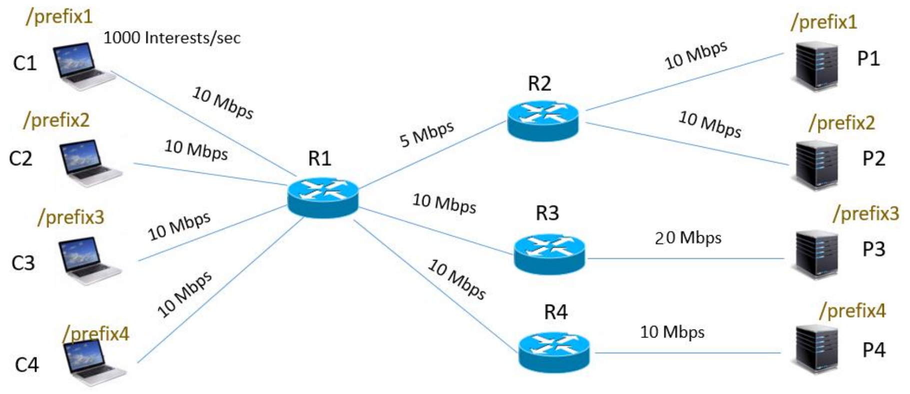
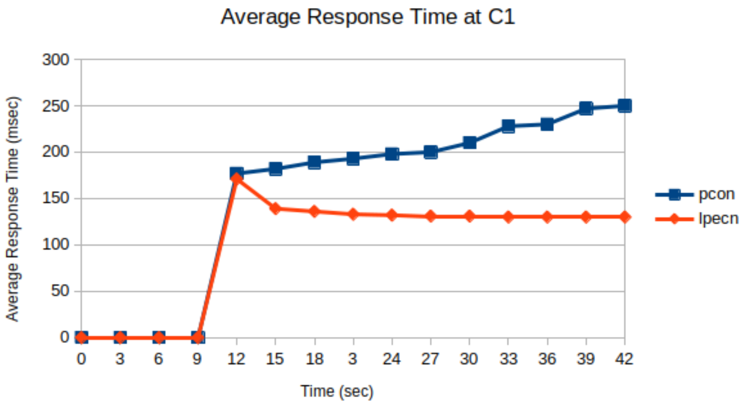


Figure 8: Topology 1.



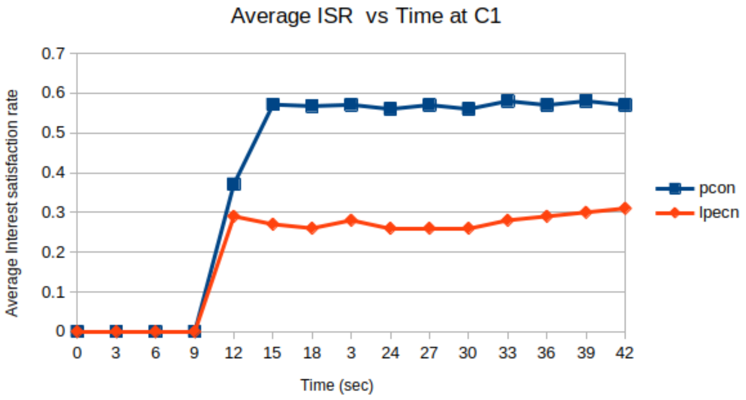


Figure 12:Average Goodput, Response Time and ISR at consumer C1 in PCON and LPECN scheme

Performance Analysis

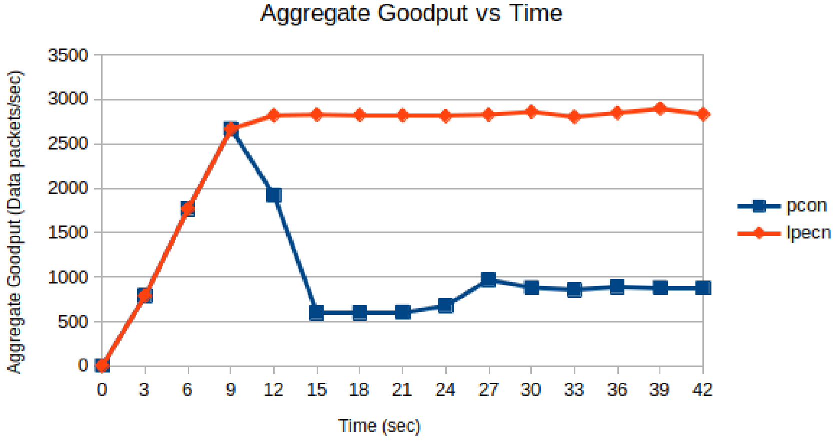


Figure 13:Aggregate Goodput in PCON and LPECN scheme

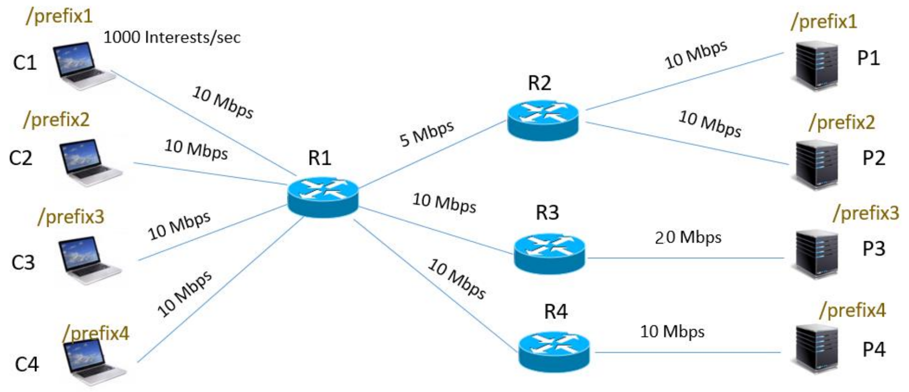


Figure 8: Topology 1.

Conclusion and Future work

- ❑ In this paper, we have shown the benefit of PIT per outgoing placement from congestion control perspective.
- ❑ We have utilized NACK and congestion marking to detect and limit Interests from non-responsive consumers, which is possible due to NDN's architectural features: stateful forwarding plane and symmetric forwarding.
- ❑ Simulation results show that LPECN can successfully handle Interests from non-responsive consumers such that others which follow congestion control scheme do not get affected.

- ❑ In future, we aim to define fairness in NDN and evaluate the fairness of LPECN.

Thank You !!