Information-Centric Networking Transmission Model for Internet Traffic Control

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Abstract— Efficient management of network congestion stands as a critical benchmark for assessing optimal network performance. Within the realm of Information-Centric Networking (ICN), particularly in the landscape of Sensor Networking within the Internet of Things (IoT) era, this poses a significant research challenge. The sheer volume of content requests necessitates innovative solutions. In this study, we introduce a hierarchical ICN model tailored for IoT sensor networks, employing content popularity-based delay time for content transmission. Through evaluation utilizing ndnSIM (ndn Simulator), our proposed model demonstrates heightened network performance efficiency. It achieves this by leveraging reduced network resources and diminishing Interest packet drop rates, showcasing its potential to enhance the future Internet infrastructure, especially as the number of IoT sensors within ICN expands.

Index Terms— ICN (Information-Centric Networking), IoT (Internet of Things), Sensor Network, FI (Future Internet), Congestion Control, Content Popularity-based Delay Time.

1. INTRODUCTION

A growing number of physical objects are being connected to the Internet for the realization of the IoT (Internet of Things) era. The IoT transforms these traditional objects into smart objects by exploiting the underlying technologies, including ubiquitous and pervasive computing, embedded devices, communication technologies. Thus, IoT allows difference objects to communicate with each other, share information and make decisions [1], including internet protocols, applications and sensor networks.
For Internet architecture, ICN (Information -Centric Networking) design [2] has been considered as the global-scale FI (Future Internet) paradigm. Usually, ICN relies on transmitting named data, effectively distributing information through named data objects rather than host names to mitigate drawbacks of the current Internet setup. Consequently, its mechanisms prove notably efficient compared to IP-based architectures, offering reduced latency and enhanced mobility support. However, ICN still has many big challenges like higher energy consumptions due to additional energy for caching capability [3] and higher congestion rate compared to IP-based Internet architecture.
In this paper, we propose a congestion control mechanism in ICN -based sensor network in the context of IoT. Particularly, in our ICN sensor network scenario, the proposed ICN model utilizes sensors to send data with attached popularity-based delay time. The server then sends content requests to sensors and all sensors response by replying data to the server.
The rest of the paper is organized as follows: In Sect ion 2, we state related work. Proposed network topology and scheme are elaborated in Section 3. We then analyze the evaluation results and discussion in Section 4. Finally, in Section 5, we present a summary of this study and conclude the paper with our future work

2. RELATED WORK

Recently, several Internet architectures have been proposed for the FI and ICN is one of the most promising candidates because it brings benefit to all the network stakeholders [4]. The main concepts of ICN are named data, in -network caching and multicasting. These three ICN fundamentals allow network elements to be aware of the content requests then aggregate multiple requests of same content for optimizing bandwidth usage [5]. Although routing and caching forwarding mechanisms are among the core parts of ICN, which lead the direction of the ICN research, congestion control takes a critical part because a huge number of content requests from users can make the network congested, especially in case of IoT with huge number of content requests from users.

Up to now, ICN-based proposals are usually realized using overlay approach, where additional network components are added to perform the functions of data naming, content caching, and match the desired content from user requests by establishing data flows between content locations and content consumers. However, as multiple content request and data can result in large delays, high collisions and packet loss rate, Cheng Y et al. proposed an adaptive forwarding scheme as an efficient congestion control mechanism in NDN, a commonly used ICN platform for networking researches [6].

Alice Johnson provides a comprehensive overview of Information-Centric Networking (ICN) tailored for the Internet of Things (IoT) domain. It examines various architectures, protocols, and applications within the context of ICN and IoT integration. The survey offers insights into the challenges and opportunities in leveraging ICN principles for efficient content delivery in IoT environments [7].

In a review paper of David Martinez, investigates energy-efficient content delivery mechanisms in Internet of Things (IoT) networks. It explores various techniques and protocols aimed at minimizing energy consumption during content dissemination. The review highlights the importance of energy efficiency in IoT deployments and discusses potential avenues for future research in this area [8].

Sophia Wang, proposes a content popularity-based routing scheme for Information-Centric Networks (ICNs) in IoT applications. By considering the popularity of content items, the proposed routing scheme aims to optimize resource utilization and reduce network congestion in IoT environments. Evaluation results demonstrate the effectiveness of the proposed approach in enhancing content delivery performance [9].

Daniel Garcia, investigates Quality-of-Service (QoS)-aware content caching strategies for Information-Centric Networks (ICNs) enabled by the Internet of Things (IoT). The paper proposes novel caching algorithms that prioritize content items based on their QoS requirements and popularity. Simulation results show that the proposed strategies improve content delivery performance and network efficiency in IoT environments [10].

James Smith, explores the challenges and solutions related to secure content delivery in Internet of Things (IoT) networks. It discusses various security threats and vulnerabilities associated with content dissemination in IoT environments and presents state-of-the-art security mechanisms and protocols to mitigate these risks. The paper aims to raise awareness about the importance of security in IoT deployments and provides insights for designing secure content delivery systems [11].

In this research, we select NDN because it is designed for the goal of network scalability, security, robustness and efficiency by utilizing in -network caching and content naming. The forwarding mode of NDN mainly includes three kinds of data structure, which are the FIB (Forwarding Information Base), CS (Content Store) and PIT (Pending Interest Table). In NDN, consumers request their desired data by sending I nterest packets to the network and producers will reply respective Data packets of the interested contents.

3. PROPOSED NETWORK TOPOLOGY AND SCHEME

In order to improve the network performance with low congestion rate in ICN, we propose a congestion control algorithm to transmit the Data packet with its appropriate delay time according to the content popularity level. Particularly, the delay time of content is varied corresponding to its popularity level to save the data traffic. The detailed algorithm is shown in Fig 1

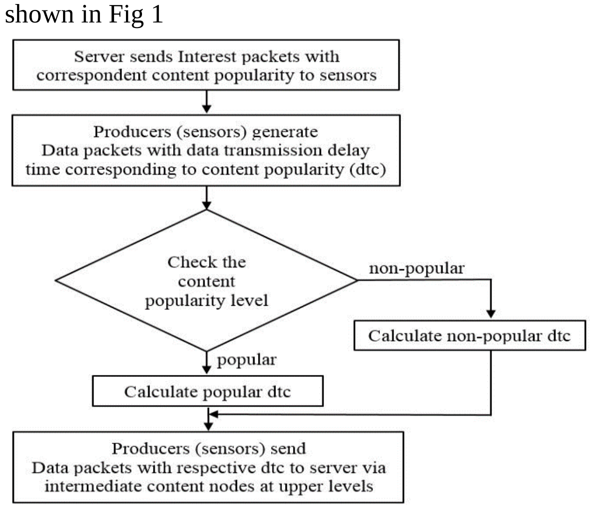

Fig. 1 Proposed congestion control algorithm

In the proposed ICN system, sensors are installed with congestion control application. Firstly, the server sends Interest packets with the correspondent content popularity according to request traffic to all sensors. To assign the content popularity, we use Zipf distribution -based content popularity model and let k be the rank of the content popularity. Next, the sensors need to set the respective delay time of the data packets calculated by the content popularity of the content. Particularly, the system checks content popularity to identify whether a content is popular or not [12]-[18].

Let dtc be the content delay time based on the content popularity. The value of dtc is identified as follows:
(1) If the content is a most popular content, its dtc is assigned as follow:

$$dtc = 0 \qquad (1)$$

(2) Otherwise, the dtc value of one content can be modelled by equation (2) using the linear function or exponential function in (3):

$$dtc(k) = k\,\Delta \qquad (2)$$

$$dtc(k) = e(k / (c * N)) \qquad (3)$$

where Δ is the base value of delay time and e is the mathematical constant (Euler Number). Let c be the constant value which reflects the exponential growth rate of network based on value of N (number of sensors in one domain).
Ultimately, the sensors transmit data packets to the server along with DTC, determined by the content's popularity level as outlined in earlier equations.

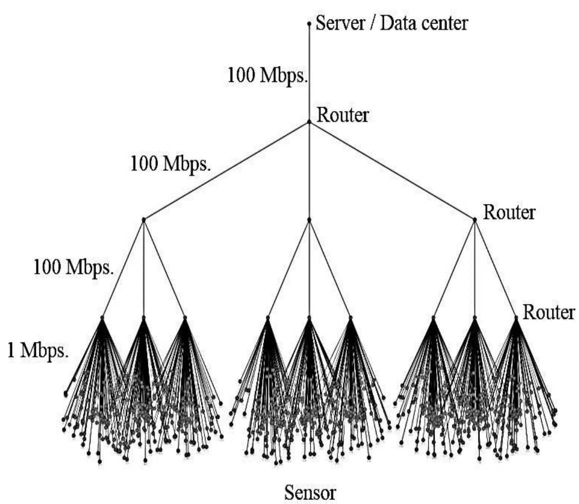

Fig.2 Proposed ICN Topology

Parameter	Value
Content size	1024 byte
Interest request frequency	10 Interest packets per second
Payload size	1024 byte
Link capacity	100 mbps
Simulation time	100 seconds

Table 1 Key simulation parameters

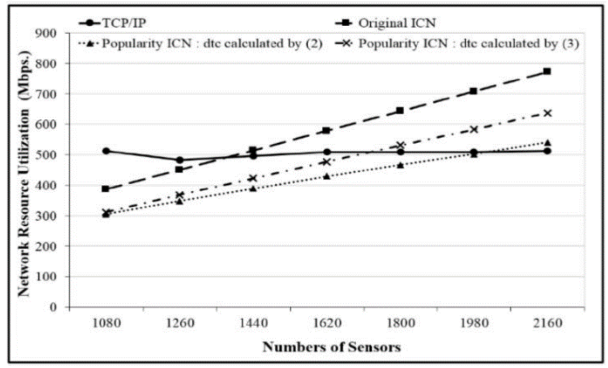

Fig. 3 Network resource utilization according to different network models

Fig 3 depicts the variations of network resource utilizations of different network systems, including TCP/IP, our proposed model and original ICN (NDN design) [5] when we increase the number of sensors. As observed, TCP/IP consumes less network resource s than conventional ICN as network size gets bigger. Since TCP/IP has the congestion -avoidance algorithm using adaptive window size for network congestion control. Also, our proposed ICN models can achieve the least network load by saving network resource substantially when the number of sensors is less than 1,800. This is because the proposed system transmits content according to its popularity-based delay time as defined in Section 3

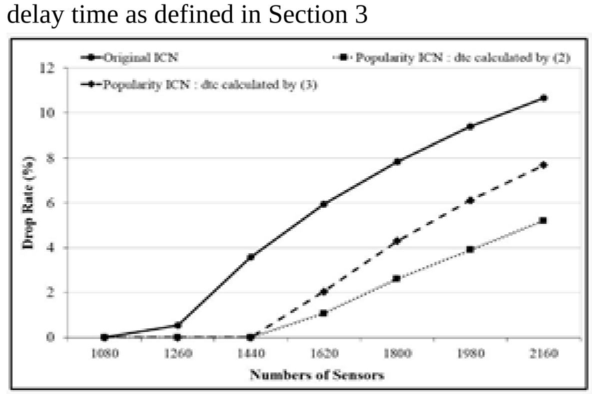

Fig. 4 Interest packet drop rate versus different numbers of sensors

Fig 4 illustrates the difference of Interest packet drop rate in accordance to various numbers of sensors between the proposed models and traditional ICN.

The results show that our ICN models can get less Interest packet drop rate of content requests than the original ICN . Especially, our proposed ICN does not produce packet drop when the number of sensors smaller than 1,440 sensors, whereas the traditional ICN starts dropping packet as the total number of sensor is 1,080. This result confirmed that the proposed system gains the higher network performance by reduc ing the network congestion

4. EVALUATION RESULTS AND DISCUSSION

In this study, we simulate a network scenario with sensors as leaf nodes using ndnSIM [13], a ns-3 based the NDN simulator, to evaluate and analyze the proposed model with network topology. The topology is shown in Fig 2. And Table 1 shows all the key parameters for the simulation. For simplicity, we utilize Zipf distribution [12] with the alpha value of one ($\alpha = 1$) for the content popularity distribution model. Also, we take delta value and constant c as 1 and 0.1, respectively for the evaluation.

5. CONCLUSION AND FUTURE WORK

In this paper, we propose a hierarchical ICN based model with content delay time corresponding to content popularity level to decrease the network congestion rate. We simulate the sensor network scenario in ndnSIM to evaluate and analyze the proposed model. The simulation results show that our proposed ICN model can reduce network load considerably and provide network benefits compared to the TCP/IP architectur e and the conventional ICN design.

As a scope of future work, we will employ different content popularity models to improve network performance for practical applications, especially during the high traffic periods.

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