A Study on Medium Access Control for Throughput Maximization in IoT networks

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Abstract- Internet of Things (IoT) is an ecosystem of connected physical objects such as sensors, vehicles, electronic equipment's etc. that are accessible through the internet. With increasing number of users, large data being generated and limited bandwidth available for IoT macro-cells, efficient multiplexing techniques are needed that use the available bandwidth efficiently. Non-Orthogonal Multiple access is a technique in which multiple users data is separated in the power domain and it is one of the most effective multiplexing techniques. The major challenges with NOMA based IoT networks are decreasing throughput with increasing path loss factor, increase in throughput with increased power levels but reduced battery life of IoTDs and BER degradation for far or weak users. Medium Access Control (MAC) plays a critical role in managing access to the transmission medium in a network. By defining access rules, preventing data collisions, incorporating QoS mechanisms, ensuring synchronization, and using addressing mechanisms, MAC protocols help to ensure that data is transmitted efficiently and reliably in a network.The paper presents a comprehensive review on Medium Access Control (MAC) for NOMA enabled IoT networks.

Index Terms:- Internet of Things (IoT), Medium Access Control (MAC), Multiple Access, Non – Orthogonal Multiple Access (NOMA)

I. INTRODUCTION

The Internet of Things (IoT) refers to the interconnection of physical devices, vehicles, buildings, and other objects through the internet, enabling them to collect and exchange data. The applications of IoT are vast and diverse, and they are transforming industries and society in various ways. Here are some of the applications of IoT:

Smart homes and buildings: IoT enables the automation of homes and buildings, providing convenience, security, and energy efficiency. Smart thermostats, lighting, and security systems can be controlled through a smartphone app, and IoT sensors can detect and respond to changes in temperature, humidity, and other environmental factors.

Fig.1 The IoT Framework

Industrial automation and manufacturing: IoT is being used to automate and optimize manufacturing processes, reducing costs, increasing efficiency, and improving quality. IoT sensors and analytics can monitor equipment performance, detect faults, and predict maintenance needs, minimizing downtime and maximizing productivity.

Healthcare and wellness: IoT is being used to monitor and track patient health, enabling remote patient monitoring, personalized treatment plans, and real-time health data analytics. IoT-enabled wearable devices can track fitness, heart rate, sleep patterns, and other health metrics, providing individuals with insights into their health and wellness.

Transportation and logistics: IoT is being used to optimize transportation and logistics, improving supply chain visibility, and reducing costs. IoT sensors can track the location and condition of goods in transit, enabling real-time tracking and alerting of any issues or delays.

Agriculture: IoT is being used to optimize agricultural processes, improving crop yields, reducing waste, and conserving resources. IoT sensors can monitor soil moisture, temperature, and nutrient levels, enabling precise irrigation and fertilization.

Smart cities: IoT is being used to create smart cities, enhancing public services, improving quality of life, and reducing environmental impact. IoT sensors can monitor air quality, traffic flow, and energy consumption, enabling real-time optimization of urban systems.

II. Bandwidth Management in IoT

Bandwidth management in IoT is critical to ensure that IoT devices can transmit and receive data efficiently without overloading the network. Bandwidth management involves optimizing network capacity and managing the flow of data to ensure that it is prioritized based on its importance and urgency. They key techniques in this domain are:

Prioritizing data: IoT networks can prioritize data based on its importance and urgency, using Quality of Service (QoS) mechanisms. This ensures that critical data, such as emergency alerts or safety-related data, is given priority over less important data.

Data compression: IoT devices often transmit small packets of data, and data compression techniques can be used to reduce the size of these packets, optimizing network bandwidth.

Data aggregation: IoT devices can aggregate data before transmitting it, reducing the number of transmissions required and optimizing bandwidth usage.

Data filtering: IoT devices can filter data at the source, removing redundant or unnecessary data before transmitting it, further optimizing bandwidth usage.

Edge computing: Edge computing involves processing data closer to the source, reducing the amount of data that needs to be transmitted over the network. This can be used to optimize bandwidth usage by reducing the amount of data that needs to be transmitted to a central server.

Predictive maintenance: Predictive maintenance involves using data analytics to predict equipment failures before they occur, enabling maintenance to be performed proactively. This reduces the amount of data transmitted over the network, optimizing bandwidth usage.

The major multiplexing techniques in this regard are:
1) FDM
2) OFDM
3) NOMA

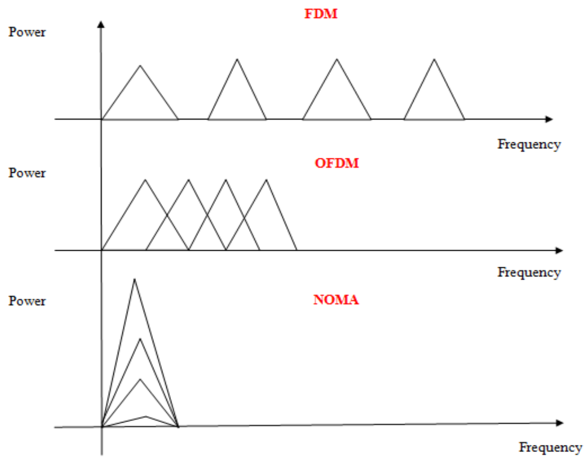

Fig.1 Comparative Spectra of FDM, OFDM and NOMA

NOMA possesses the maximum bandwidth utilization.

II. LITERATURE REVIEW

The following section presents the previous work in the related field.

Xu et al. proposed an uplink secondary Internet of Things (IoT) device scheduling and power allocation problem based on imperfect channel state information (CSI) and imperfect spectrum sensing is investigated for industrial cognitive IoT over cognitive heterogeneous non-orthogonal multiple access (NOMA) networks. The joint secondary IoT device scheduling and power allocation problem maximizes the network throughput subject to total power constraint at each secondary IoT device, to increase the throughput based on a cognitive approach.

Zhao et al. provides an overview of the state-of-the-art in NOMA-based IoT communication systems. It discusses the benefits of NOMA for IoT, including increased capacity, improved reliability, and reduced latency. The paper also explores various NOMA-based techniques, such as power-domain NOMA and code-domain NOMA, and discusses their advantages and challenges.

Wang et al. proposed a power allocation scheme for NOMA-based IoT networks with energy harvesting. The scheme is designed to maximize the overall throughput of the network while ensuring that the energy harvested by each IoT device is sufficient for its transmission needs. Simulation results show that the proposed scheme outperforms traditional OMA-based power allocation schemes.

Choi et al. proposed a joint channel estimation and signal detection scheme for NOMA-based IoT networks. The scheme is designed to improve the accuracy and efficiency of channel estimation and signal detection, enabling more reliable and efficient communication. Simulation results show that the proposed scheme outperforms traditional OMA-based channel estimation and signal detection schemes.

Alodeh et al. proposed an energy-efficient resource allocation scheme for NOMA-based IoT networks with limited feedback. The scheme is designed to optimize the power allocation and modulation schemes for each IoT device while minimizing the overall energy consumption of the network. Simulation results show that the proposed scheme outperforms traditional OMA-based resource allocation schemes.

III. MEDIUM ACCESS CONTROL

This section presents the concept of medium access control (MAC). Medium Access Control (MAC) is a sublayer of the Data Link layer in the OSI model that is responsible for managing access to the transmission medium in a network. The MAC layer ensures that multiple devices can access the transmission medium in an orderly and efficient manner, without interfering with one another.

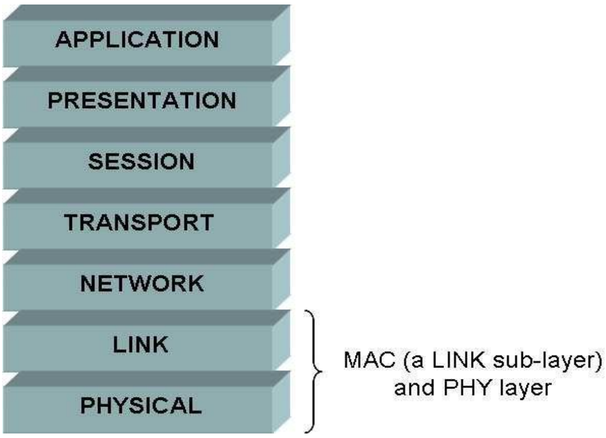

Fig.3 MAC Layer in OSI Model

MAC protocols: MAC protocols define the rules for how devices can access the transmission medium. There are several types of MAC protocols, including Carrier Sense Multiple Access (CSMA), Time Division Multiple Access (TDMA), and Code Division Multiple Access (CDMA). Each protocol has its own advantages and disadvantages, and the choice of protocol depends on the specific requirements of the network.

Collision avoidance: Collision avoidance is a key function of MAC that helps to prevent data collisions between devices. Collision avoidance techniques include Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) and Token Passing. These techniques help to ensure that only one device can transmit at a time, reducing the likelihood of data collisions.

Quality of Service (QoS): MAC protocols can also incorporate QoS mechanisms that prioritize certain types of traffic over others. For example, QoS mechanisms can be used to give priority to real-time traffic, such as voice or video, over non-real-time traffic, such as email.

Synchronization: Synchronization is another key function of MAC that helps to ensure that devices are synchronized with each other. Synchronization mechanisms ensure that devices can correctly interpret and respond to signals from other devices on the network.

Addressing: MAC also includes addressing mechanisms that help devices to identify and communicate with each other. These addressing mechanisms can include MAC addresses, which are unique identifiers assigned to each device on the network.

Maximizing throughput is a critical challenge in IoT networks, as these networks typically involve a large number of low-power devices that generate a high volume of data. To achieve high throughput in IoT networks, several techniques can be used, including:

Multiple access techniques: Traditional multiple access techniques, such as time division multiple access (TDMA) and frequency division multiple access (FDMA), can be used in IoT networks to maximize throughput. These techniques enable multiple devices to access the network simultaneously without interference, increasing the overall network capacity. MIMO techniques: Multiple input multiple output (MIMO) techniques can be used to increase the throughput of IoT networks. MIMO technology uses multiple antennas at both the transmitter and receiver to increase data transfer rates, improve signal quality, and reduce errors.

Cognitive radio: Cognitive radio is a technology that enables devices to dynamically adapt their transmission parameters, such as frequency and power, based on the current network conditions. This technology can be used in IoT networks to optimize network capacity and improve throughput.

Data compression: Data compression techniques can be used to reduce the amount of data that needs to be transmitted over the network. By compressing data before transmission, less bandwidth is required, enabling more data to be transmitted within a given time period. Traffic prioritization: Prioritizing network traffic can also improve network throughput in IoT networks. By giving priority to critical data, such as real-time sensor data, over non-critical data, such as periodic status updates, the overall network throughput can be improved. There is a trade off between the system throughput and the BER defined as:

BER is defined as:

$$BER = \frac{No\ of\ Error\ Bits}{Total\ Number\ of\ Bits} \quad - \quad (1)$$

The throughput is defined as:

$$Throughput = \frac{Data\ Size}{Time} \quad (2)$$

Conclusion: Non-Orthogonal Multiple Access (NOMA) is an emerging technology that has the potential to significantly improve the efficiency and capacity of wireless communication systems. In recent years, researchers have been exploring the use of NOMA in IoT networks, which can help overcome the limitations of traditional orthogonal multiple access (OMA) techniques. This paper presents a comprehensive review on the existing work in the domain for medium access control for NOMA enabled IoT networks.

REFERENCES

[1] L Xu, W Yin, X Zhang, Y Yang, "Fairness-Aware Throughput Maximization over Cognitive Heterogeneous NOMA Networks for Industrial Cognitive IoT", IEEE 2022

[2] Xiaojuan Zhao, Shouyi Yang, Aihua Zhang, Xiaoyu Li, "A Compressive Sensing Based Multi-user Detection Algorithm for SIMO-NOMA Systems", IEEE 2021

[3] B Wang, L Dai, Y Zhang, T Mir, "Dynamic compressive sensing-based multi-user detection for uplink grant-free NOMA", Vol-20, Issue-11, IEEE 2020

[4] J Choi, J Mo, RW Heath, "Near maximum-likelihood detector and channel estimator for uplink multiuser massive MIMO systems with one-bit ADCs", Vol-64, Issue-5, IEEE Xplore- 2019

[5] Maha Alodeh ; Symeon Chatzinotas ; Björn Ottersten, "Energy-Efficient Symbol-Level Precoding in Multiuser MISO Based on Relaxed Detection Region", Vol-15, Issue-5, IEEE Xplore- 2018

[6] Fabian Monsees ; Matthias Woltering ; Carsten Bockelmann ; Armin Dekorsy, "Compressive Sensing Multi-User Detection for Multicarrier Systems in Sporadic Machine Type Communication", IEEE 2017

[7] S Wang, Y Li, J Wang, "Multiuser detection in massive spatial modulation MIMO with low-resolution ADCs", IEEE Transactions on Wireless Communication, Vol-14, Issue-4,available at IEEE Xplore, IEEE 2016

[8] S Narayanan, MJ Chaudhry, A Stavridis, "Multi-user spatial modulation MIMO", Proceedings of Wireless Communications and Networking Conference (WCNC), available at IEEE Xplore, IEEE 2014

[9] P Botsinis, D Alanis, SX Ng, LLCSO Hanzo, "Quantum-Assisted Multi-User Detection for Direct-Sequence Spreading and Slow Subcarrier-Hopping Aided SDMA-OFDM Systems", IEEE 2014

[10] A Mukherjee, SAA Fakoorian, J Huang, "Principles of physical layer security in multiuser wireless networks: A survey", Vol-16, Issue-3, IEEE 2014

[11] Rui Bai, Samuel Palermo, Patrick Yin Chiang, "A 0.25pJ/b 0.7V 16Gb/s 3-Tap Decision-Feedback Equalizer in 65nm CMOS", IEEE 2014

[12] Deniz Kilinc, and Ozgur B. Akan, "Receiver Design for Molecular Communication", IEEE 2013

[13] Rodrigo C. de Lamare, "Adaptive and Iterative Multi-Branch MMSE Decision Feedback Detection Algorithms for Multi-Antenna Systems", IEEE 2013.

[14] Shayan Shahramian, Hemesh Yasothara, and Anthony Chan Carusone, "Decision Feedback Equalizer Architectures With Multiple Continuous-Time Infinite Impulse Response Filters", IEEE 2012.

[15] Peng Li and Rodrigo C. de Lamare, "Adaptive Decision Feedback Detection with Constellation Constraints for MIMO Systems", IEEE 2012.

[16] Chao Zhang, Zhaocheng Wang, Changyong Pan, Sheng Chen, and Lajos Hanzo, "Low-Complexity Iterative Frequency Domain Decision Feedback Equalization", IEEE 2011.

[17] Georg Tauböck, Mario Hampejs, Pavol Sva ˇ c, Gerald Matz, ˇFranz Hlawatsch, and Karlheinz Gröchenig, "Low-Complexity ICI/ISI Equalization in Doubly Dispersive Multicarrier Systems Using a Decision-Feedback LSQR Algorithm", IEEE 2011

[18] Chao Zhang, Zhaocheng Wang, Zhixing Yang, Jun Wang, and Jian Song, "Frequency Domain Decision Feedback Equalization for Uplink SC-FDMA", IEEE 2010

[19] T Liu, JK Zhang, KM Wong, "Optimal precoder design for correlated MIMO communication systems using zero-forcing decision feedback equalization", IEEE 2007.

[20] M Eroz, LN Lee, "Low rate coded interleave division multiple access on Rician fading channels", IEEE 2007