Fair Bandwidth Multi-channel Allocation Scheme for IoT

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Abstract: *The multi-channel allocation that meets several Quality of Service (QoS) constraints is substantial for supporting heterogeneous traffics in the Internet of Things (IoT). The existing multi-channel allocation schemes are not friendly and dynamic for heterogeneous traffics in IoT environment. The wireless network is characterized by its limited power, shared media and dynamic topology. The proposed scheme is designed to tackle the demanding problem of fair multi-channel allocation scheme for heterogeneous traffics in IoT environment. The proposed multi-channel assignment algorithm allocate channel based on the node identification (ID). The simulation is done in software Network Simulator-2 (NS-2) and the experimental results showed that the proposed algorithm achieved better performance in the term of less delay, less energy consumption and high throughput. The comparative analysis of both single and multi-channel are also performed. The experimental results showed that the multi-channel scheme is the best solution that provides a better and more reliable MAC protocol for the users.*

Keywords: *Internet of Things (IoT); Multi-channel; Bandwidth, MANETs*

1. Introduction

The IoT is a novel paradigm which consists of a complex network of objects embedded with electronic systems for efficient exchange and utilization of data. It is gaining popularity because it integrates several technologies to provide smarter services to the users. The basic idea of the IoT is to develop a technology that connects physical things such as buildings, sensors, mobile devices, actuators etc. through wired and/or wireless networks. The IoT has become an active research area with special emphasis on the resources constraints of devices such as power, channels and computation power [1].

Multimedia traffic such as video, images and video conferencing is overwhelmingly increasing. This traffic requires QoS being the basic need of every mobile user. To achieve QoS, an efficient and rapid network is desirable [2].

IoT may be connected through the wired or wireless networks. Mobile Adhoc Network (MANETs) is the wireless networks that have decentralized nature consisting of mobile nodes. All the nodes in MANETs are peers. In packet delivery process, every node performs the function of the source and also the target node. Additionally, it may perform the function of the router as well. This means all the nodes have equal rights. Adhoc networks gained popularity due to its low cost, easy deployment and configuration less setup. The range applications of MANETs are quite vast including disaster applications, military, rescue, wireless sensor networks, wireless mesh networks and collaborative computing. MANETs have some special characteristics and many advantages, but

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at the same time, there are many issues, including mobility management, resource management and security management to be resolved [3].

Routing in IoT environment is a very challenging task for many applications. Both single and multi-path routing algorithms and bandwidth utilization for IoT environments are the main consideration for the researchers. Multi-path routing improves the reliability and robustness of the network. The performance of the single path routing protocol is worse when the traffic is high and the network size is large. In case of heavy traffic and high network size, a systematic procedure is required for channel allocation, which makes the designing of routing more difficult [4].

In this paper, the problem of multi-channel allocation scheme for heterogeneous traffics in IoT is addressed. All nodes are of mobile nature and access to the medium is the key issue. Providing a fair segment of medium to all nodes and utilizing channel in the best way is required. Medium Access Control (MAC) layer plays a vital role to manage the shared media to all communicating nodes and it has some basic requirements such as control overhead ratio must be kept less, channel distribution among the nodes shall be done in a fair way, and the channel utilization shall be done in the best way. To achieve these requirements intelligent bandwidth reservation algorithm is required for IoT environments.

The remaining paper is organized as follows: section II elaborates related works, section III describes the proposed solution, and section IV presents the experimental results and discussion. Conclusion and future work are drawn in section V.

2. Related Works

Designing a QoS based routing techniques for IoT environments have been done extensively during the last decade. The majority of work is based on protocol designing for IoT environments considering energy efficiency. A brief overview of single and multipath based routing protocols performances in the IoT environment is presented here.

Huang et al. [5] addressed the issue of multicast routing for multimedia traffics in IoT. The authors designed the algorithm that has the ability to establish point-to-multipoint trees for meeting multiple QoS required multimedia traffics. The experiment results show that the proposed algorithm is more efficient in terms of speed and accuracy. The proposed algorithm is more suitable for the dynamic network environment in IoT. In [6], authors have discussed the Machine to Machine (M2M) communication technology and highlighted the challenging problem of M2M communication technology. Software Defined Wireless Sensor Network architecture (Soft-WSN) for IoT application is designed in [7]. The experimental results show that the proposed software is more beneficial for the real-time application specific requirements of IoT. Software define network based load balancing is used to manage the huge traffic load which distribute the load among different servers [8]. In [9], authors have designed a three-layer reference model for Wireless Sensor Network Monitoring Platforms (WSN-MP) IoT applications. The first layer is the monitoring layer, second is information layer and the last one is the interchange layer. Awan et al. [10] discussed the issue of delay sensitive traffic QoS requirements in IoT environments. The testing results show that proposed scheme achieves high QoS for IoT devices. The supervision and management of SLA are the critical issues because the IoT builds large applications [11]. To provide the real-time monitoring algorithm is proposed that is based on the theory of Discrete Event System (DES). It automates the generation of QoS-aware services. The experiment results show that proposed approach achieves the high QoS. In [12], the authors discussed the issue of the web based and cloud based services QoS requirements. Kernel least mean square algorithm (KLMS) is proposed for the QoS requirements. The proposed algorithm achieves the best prediction accuracy. In [13], the issue of privacy for IoT in share environment is considered. They have designed the privacy aware channel access approach for IoT and the proposed approach is based on the novel zero-exposure slot allocation scheme. The experiment results show that channel access performance is absolute cross-trust-domain identity exposure. In [14], the authors discussed the channel access issue for the billions of smart devices in IoT. In this

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paper, they have designed the channel access model for the 5G IoT green wireless communication and the scheme is called smart sounder scheme. The experimental results show that smart sounder scheme can work effectively. Saleemet al. [15] discussed the three critical aspects of the IoT such as QoS, energy efficiency and balancing. To solve these issues, the authors designed a new Radio Frequency (RF) energy harvesting scheme, cluster head method, and intelligent channel selection method. The simulation results show that the proposed scheme performs better than existing scheme.

In [16], the authors have considered the multipath based routing protocol that provides the reliable routing scheme for congestion traffics. Simulation results show that it achieves high throughput with reduced delay. In [17], the proposed protocol is based on the multipath based routing scheme. It selects the route that is energy aware. High throughput, less energy consumption and reduced end to end delay is the simulation achievement. In [18], the authors studied the previous single and multipath based QoS routing protocols and discussed the QoS parameters. In [19], the proposed algorithm is based on the ant algorithm and is most suitable for the mobility environment. It considers two parameters to select the route. First one is link quality and the other is link delay. In [20], the authors have discussed the robust path issue for multihop Wireless Sensor Network (WSN). This protocol is more useful for large scale networks. High throughput and reduced end to end delay is the feature of this protocol. In [21], the authors take the delay issue and proposed bypassing void routing protocol. The simulation results show that it achieves high throughput and reduced delay. In [22], the proposed protocol is based on multipath routing for MANETs and it is based on the biological attracter selection scheme. The simulation results show that the proposed protocol achieves higher throughput and data delivery ratio due to the use of multipath. In [23], the authors take the mobility issue for multimedia applications and designed bottom up a routing protocol that uses Artificial Neural Networks (ANN) techniques for routing. Experimental results show that enhanced levels of QoS in a diversity of multimedia and mobility scenarios. In [24], the authors have used the fuzzy logic algorithm and designed stable and energy-efficient routing technique. It considers the link reliability parameter for routing estimation. The results show that it achieves the reduced energy consumptions and improved the packet delivery ratio. A similar approach is developed in [25]. In [26], Multi-constrained and Multipath QoS Aware Routing Protocol (MMQARP) is designed to address the delay issue for delay sensitive applications. In the route selection it considers two parameters link reliability and energy efficiency. In [27], the authors have discussed the QoS management framework for MANETs for the real time applications. The proposed framework achieves the higher throughput. In [28], the authors have designed Context Aware Adaptive Fuzzy (COAAF) protocol. The proposed protocol is useful for variable services and network traffic intensity and experiment result shows the best route selection. In [29], the authors have proposed a protocol that is based on the traffic splitting algorithm. It takes the QoS parameters such as bandwidth, delay and path reliability and, then finds the multipath for the transmission. The proposed protocol achieves higher throughput, reduce packet drop and delay in the transmission. In [30], the authors have developed the energy efficient coding aware cluster based protocol scheme. It improves the performance of network with respective to reduce energy consumption and increases lifetime of the network. In [31], the authors have added the QoS metrics such as energy awareness feature to Temporally Ordered Routing Algorithm (TORA) routing protocol based on the Binary Particle Swarm Optimization algorithm (BPSO). The proposed protocol calculates the routing lengths and energy level of the route then selects the route of transmission. It is based on the single path routing. It achieves the high data rate and prolong the network lifetime. The main shortcoming of this protocol is the routing overhead. The work in [32], have taken the channel distribution issue. In [33], the authors have designed an algorithm that is based on the Fixed-Tree Relaxation-Based Algorithm (FTRA). Route optimization is the feature of this algorithm and it achieves the minimum energy consumptions. In [34], the authors have added

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the feature of Binary Particle Swarm Optimization algorithm (BPSO) to the TORA routing protocol that considers the routing length and energy level. The experimental results show that protocol performs well in terms of selection of these parameters the results show higher throughput with reduced delay. In [35], the authors have considered the multipath routing, which is more suitable for security applications in MANETs and presents the strategy to compute multiple severely disjoint paths between any two nodes in OLSR-based networks. The simulation results show better performance. The work in [36], discussed the functionality of the multipath routing.

3. Proposed Technique

The proposed multi-channel scheme for channel reservation among mobile nodes divides the channel into multi-sub-channels. For identification of N sub-channels, an ID to each sub-channel e.g.ID (0)-to- ID (N-1) is assigned. The available bandwidth is divided into the multi-channel also called sub-channels. To differentiate these sub-channels, we assigned the ID to each channel which is start from the 0 to N-1. The mathematical model utilized this ID in the channel assignment algorithm.

For the communication environment, the following mathematical formula is used to select the channel for transmission.

$$Node_{TX} = Node_{id} \bmod N$$

Where N is the total number of channel and $Node_{id}$ show the node number and $Node_{TX}$ show the current transmitting node. For example, the available bandwidth is divided into 5 sub-channels denoted by N=5 and the node which require channel for communication has the node ID 7. By using the given formula and the channel 2 will be assigned to that node.

The key achievements of this scheme: control overhead ratio is less, channel distribution among the nodes is in the fair way and makes best use of channel utilization.

3.1. Algorithm for Channel Allocation Scheme

The algorithm given in Table 1 shows the step-by-step procedure of allocation of channel to the nodes when multiple channels are available. The above architecture of the multi-channel shows the division of the channel and each channel have the unique ID that starts from 0 and ends at N-1.

Procedure: A set X of successful channel assignment request and a set of F channel free time of N channel in MANETs.

Output: A feasible channel assignment

Begin

Step-1: Numbers of nodes that are try for channel reservation are N.

Step-2: Divided the channel into sub channels such as N=10.

Step-3: $T_x = Node_{ID}$ %N

Where N show the sub channels

$Channel_{ID}$ = R (Reminder)

T_x = Reminder ($Channel_{ID}$)

Step-4: step-3 will repeated until the channel assignments done to all nodes.

$T_x = Channel_{ID}$

End

3.2. System architecture

The function and assignment of the proposed scheme is shown in Fig 1. The model shows that how a channel is reserved for the mobile nodes when they need to transmit. According to the model for channel assignment, it uses the formula $Node_{id}$ mod N. This module is connected to the Link Layer (LL). The LL sets the MAC target address in the MAC header of the packet. To resolve IPs to hardware (MAC) address conversion LL is connected to the Address Resolution Protocol (ARP). The entire query from LL is delivered to ARP. Interface Queue (IFQ) gives a priority queue to the packets. It then receives the packets and forward them based on the priority. The module MAC 802.11 is connected to the LL and LL is back connected to the MAC 802.11 and this defines how to access the channel. The MAC is connected to the Network Interface (NetIF) and NetIF is back connected to the MAC 802.11 and its basic function is to stamp each transmitted packet header with metadata that carries extra information such as wavelength, power, and propagation model. The last module shows a multichannel assigned to the mobile nodes according to the model.

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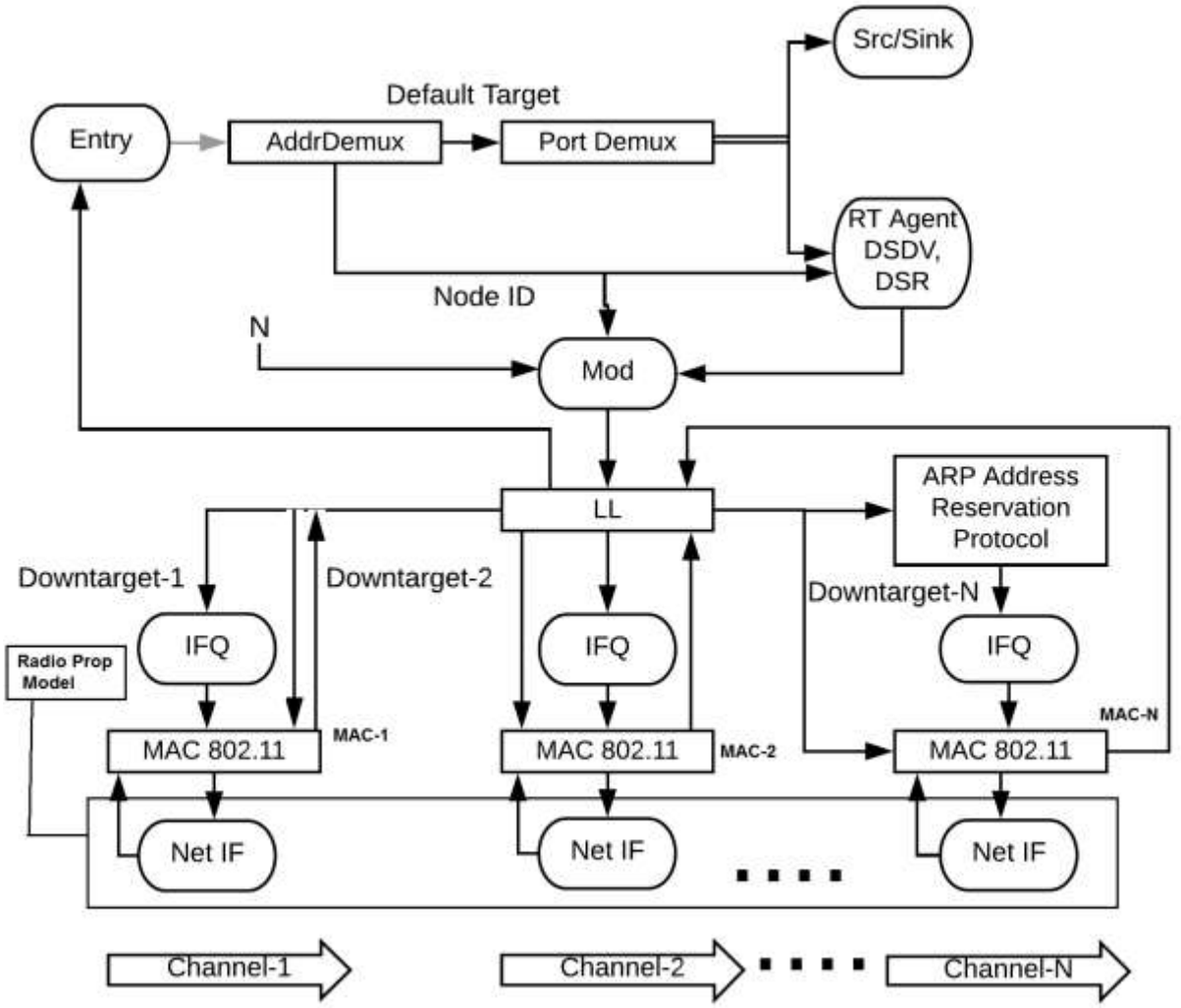

Fig.1. System Architecture

4. Simulation results and analysis

The performance of the proposed multi-channel scheme has been evaluated and compared with the existing single channel MAC protocols. For experiments, the NS-2 [37] is used. The hundred nodes moving with uniform velocity of 5 msec using the random waypoint mobility model are used for simulation. The total simulation area is divided in the square area of 1000 x 1000 meter square. Ad hoc On-Demand Distance Vector (AODV) protocol is used for routing and Constant Bit Rate (CBR) traffic sources are used with User Datagram Protocol (UDP) at the transport layer. The simulation parameters of the proposed scheme are explained in table 1.

Table 1. Parameters for simulation

Parameters	Values
Size of Networks	1000 x 1000 meter square
Number of Nodes	100
Queue Power	50 Packets
Mobility Model	Random way mobility model
PKT Size	64,128,512,1024
Flows	5,10,15,20

Based on the simulation, we judge the QoS parameter delay, throughput and energy consumption for assessment.

The QoS parameter delay is defined as the time difference of packets transmission when it sends from source node to the target node.

$\sum$ Tr-Ts/Np

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The Tr and Ts represents the receiver and sender time stamp and Np show the total number of received packets.
The QoS parameter throughput is defined as the number of bits delivered to target node in given amount of time.
Br/Bs *100
The number of sent bytes and number of received bytes is denoted by Br and Bs.

Energy consumption means that how lots of powers waste the transmitted packets and control packets mil Joule/Kbyte.
The hundred nodes communication a sample topology used in Adhoc environment simulations was shown in the below Fig. 2. The topology shows that 100 nodes are randomly distributed in 1000 x 1000 meter square area.

4.1. Test of varying Packet Size Effect

In this experiment, QoS parameters such as throughput, delay and energy consumptions are analyzed by varying the size of packets in transmitting of traffic with 100 mobile nodes.

4.1.1. Throughput

The throughput of a single and multi-channel is increased due to increase in packet size because the larger packet size carried more bits to the target node. But the performance of the multi-channel is better because it uses the sub-channel for communication. It also avoids the congestion issue. The throughput result of the single channel is affected when the packet size increases because it takes longer time in transmission. The Fig 3 clearly indicates that the multi-channel scheme is good to achieve maximum throughput in the large network.

4.1.2. Delay

The average delay of a single channel is affected in longer transmission due to chance of a collision in traffics. The multi-channel showed good results because it used multipath scheme. But when packet size increases the channel is divided into the sub-channels, multi-channel delay graph is shown in Fig 4. Its size reduced in order to carry large size packet and it faces the problem of congestion.

4.1.3. Energy consumption

The energy consumption of single channel and multi-channel scheme is analyzed and found that the energy consumption of the multi-channel is large. Since the mobile nodes are communicating at diverse channel at the same time it wastes more energy. The single channel energy consumption is less as compared to the multi-channel. The energy consumption of single and multi-channel is shown in Fig 5.

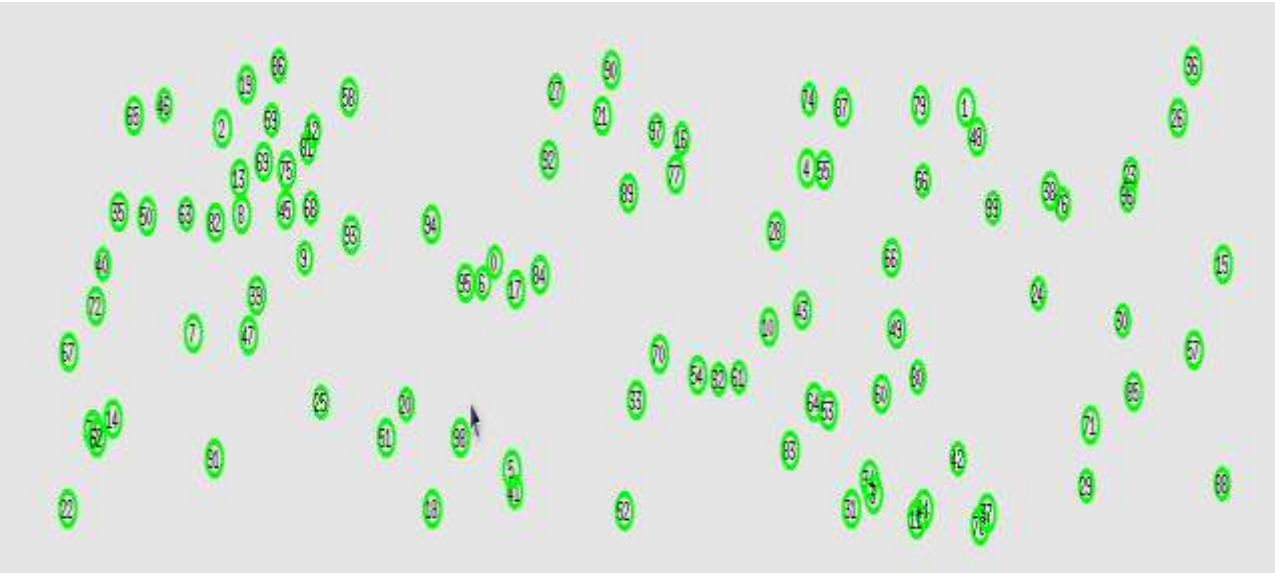

Fig.2. Topology of Sensor Nodes

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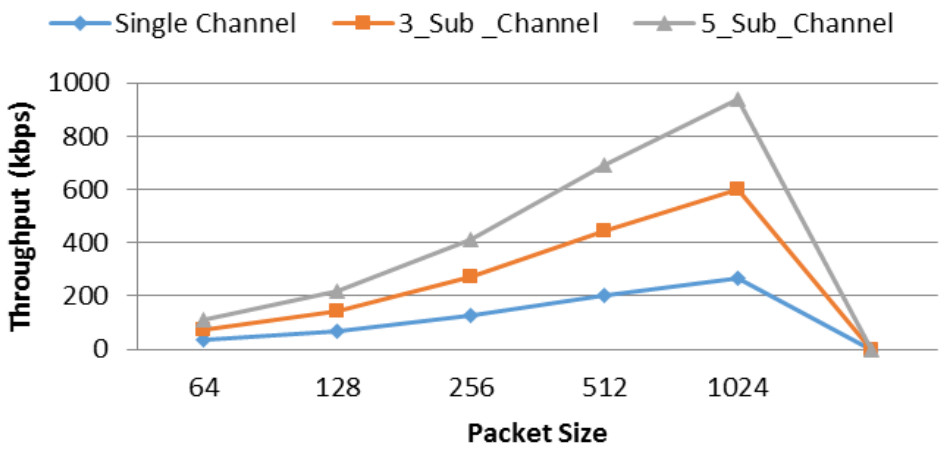

Fig.3. Throughput comparison of single and multi-channel with packet size variation

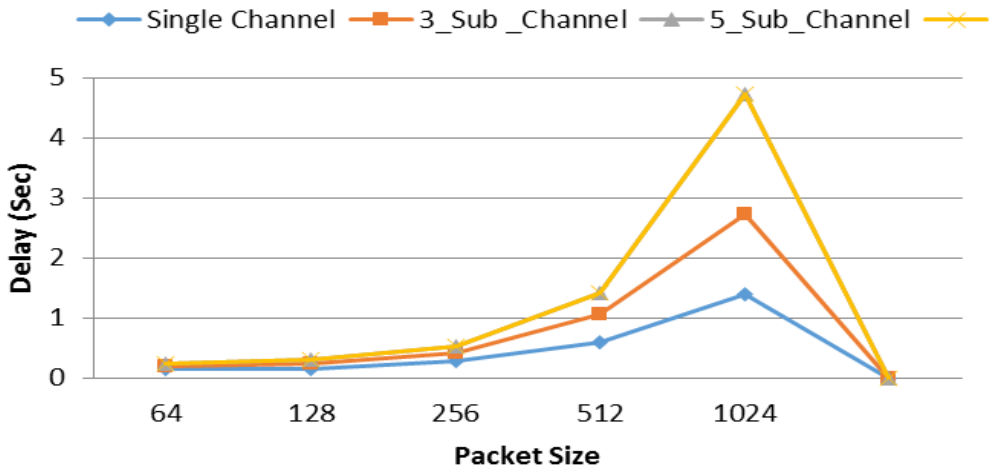

Fig.4. Delay comparison of single and multi-channel with packet size variation

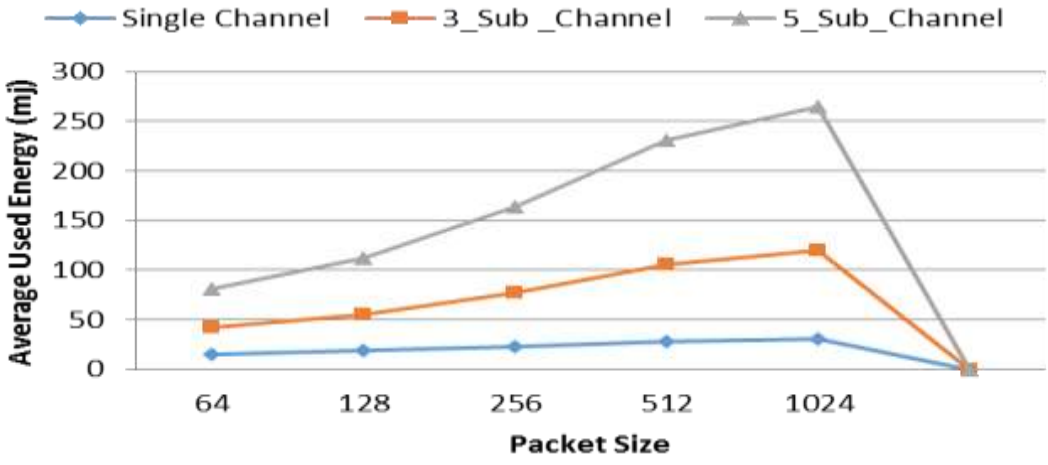

Fig.5. Energy consumption of single and multi-channel with packet size variation

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4.2. Test of varying Flows Effect

The purpose of this experiment is to evaluate the performance of single channel and multi-channel MAC protocols under varying conditions. This experiment also shows the performance variation of the proposed scheme in the congested situation.

4.2.1. Throughput

The throughput performance of multi-channel is higher than single channel, when the number of flows is increased in congested situation which reduced collisions. However, the single channel faces the collision due to congestion. Fig 6 shows the pictorial representation of multi-channel versus single channel.

4.2.2. Delay

The delay results of multi-channel are not good as compared to the single channel when the traffic flow increases. This shows that more channels are not suitable to achieve the reduced delay. The graphical comparison is shown in Fig 7.

4.2.3. Energy consumptions

When all the nodes are communicating through different sub-channels, then more bits are delivered to the target nodes so energy consumption ratio is also increased. Multi-channels are consuming more energy than single channel as shown in Fig 8.

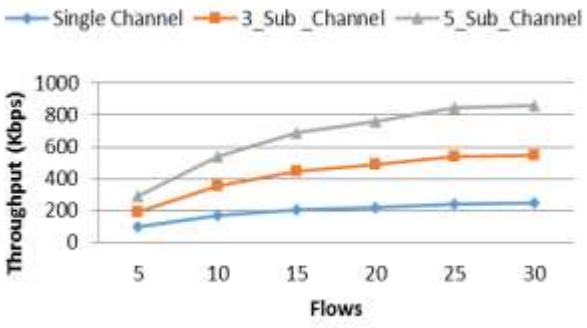

Fig.6. Comparison of single and multi-channel throughput

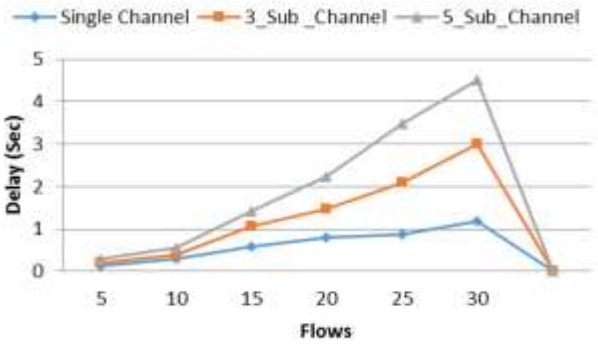

Fig.7. Delay comparison of single and multi-channel

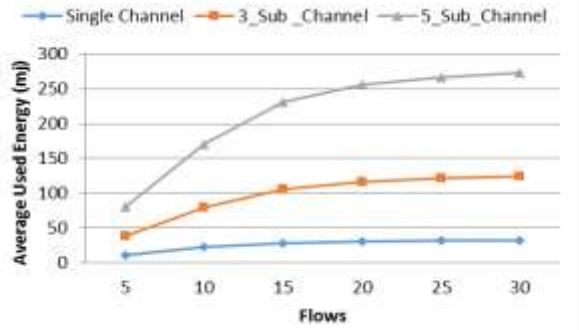

Fig.8. Energy consumption comparison of single and multi-channel

5. Conclusion and Future Work

The proposed scheme solves the issue of channel reservation among the competing nodes based on the multi-channel MAC protocols. The proposed algorithm also achieves fair channel distribution and utilization, reduces the ratio of collision and no extra control packets (overhead) are involved. Experimental results show that the proposed multi-channel reservation scheme achieves higher throughput, less delay and manage energy consumption. The comparative study of the single and multi-channels is also performed. The designed multi-channel method provides the most excellent result for IoT environment.

Bandwidth reservation for video traffics in IoT is the open issue for future investigations. The estimates about the required bandwidth in advance will be a nice information that can be further investigated.

In high traffic load condition in the IoT environment, it is difficult to meet a path for the

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heterogeneous traffics that satisfies the required bandwidth. So multipath bandwidth reservation for the heterogeneous traffics in IoT environment is also an open problem.

Intelligent technique for the channel assignment for IoT devices to optimize the QoS and energy harvesting is another open issue for future work.

IoT generates large and various kinds of traffics. Each traffic has its own QoS requirements so to define new QoS requirements and support schemes is another future direction.

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