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Dynamic Load Balancing Scheme for Relay-based Networks

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ABSTRACT
Applications have evolved for provisioning smart technology, smart services, smart industry, smart management, and smart life. However, for holistic operation in the whole network, it requires seamless communication from the sensor/actuator to the gateway. A dynamic channel allocation and organization approach is proposed in to improve the performance of relay-based large networks. A MAC protocol proposed by Kumar et al. uses a static channel allocation mechanism for the distributed relay nodes. A dynamic channel allocation and organization approach is proposed in to improve the performance of relay-based large networks. The DAC scheme divides beacon into different slots of equal duration. It uses two random variables uniformly distributed in beacon and transmission interval, respectively. The grouping mechanism in 802.11ah reduces collisions due to contention. For a large number of STAs, through put performance will be better when group size is higher. The sectorization scheme increases the network capacity and achieves superior performance over a large-scale distributed network. It can dynamically adjust bandwidth with the use of MCS with a higher data-rate.
Keywords: *IoT, RAP, MCS, DAC and STA*

I. INTRODUCTION

With the technical support from IoT, applications have evolved for provisioning smart technology, smart services, smart industry, smart management, and smart life. However, for holistic operation in the whole network, it requires seamless communication from the sensor/actuator to the gateway. The state of art solutions is not very suitable for supporting communication among a massive number of IoT devices. 802.11ah standard has emerged as new candidates to solve the above gap problem. This standard proposes some innovative and unique concepts for supporting a large number of low-power devices in smart cities. With the sup- port of the sub-1GHz frequency band, it can cover up to 1km in a hop. Along with the grouping-aware a RAW, it also proposes a Relay AP (RAP) solution, which can in- crease the coverage beyond 1-hop distance and can support more number of devices in the network. In the 802.11ah-based large-scale network, there is a possibility of poor quality data reception due to long communication range and higher delay in multi-hop transmis- sion. As it uses only a single channel, only one node in the network can transmit at a particular time. Carry on the point a little, this may cause interference on each otheror increase the chances of hidden node problems. Also, networks used in IoT solutions need to support heterogeneous traffic requirements.

II. BACKGROUND AND RELATED WORKS

To support the requirements of heterogeneous traffic in IoT, it has pro- posed different MCSs to be applied in various scenarios. Considering the wide channel of 16 MHz, MCS9 can provide up to 78 Mbps of data rates. IEEE 802.11ah utilizes sub-1 GHz license-exempt bands to provide extended coverage range. It defines 2, 4, 8, and16 MHz channel bands for data transmission.

2.1 Channelization

The channelization in 802.11ah inherits the PHY layer of 802.11ac. T he available license-exempt channels in sub-1 GHz spectrum for different countries. For example, current availability as: 902-928 MHz (US), 755-787, 614-787 MHz (China), 917-923.5 MHz (South Korea), 863-868.6 MHz (Europe), 865-867 MHz (India), 915.9-929.7 MHz (Japan), 866-869

MHz, 920-925, 866-869 MHz (Singapore) [83]. The channel bandwidth in 802.11ah includes 1, 2, 4, 8 and 16 MHz, whereas 1 and 2 MHz are widely available in many countries and more suitable for low rate traffic scenarios.

A MAC protocol proposed by Kumar *et al.* uses a static channel allocation mechanism for the distributed relay nodes. A dynamic channel allocation and organization approach is proposed in to improve the performance of relay-based large networks. Rao *et al.* introduces a dual-hop relay to extend the connectivity till STAs, however, the detail deployments in different geographic locations are not considered while placing a relay node. A cooperative relay with a cross-layer design for minimizing the power consumption of an 802.11ah network is proposed by Argyriou *et al.* None of these schemes consider the heterogeneous traffic coexisting in-elastic and elastic traffic in the same 802.11ah network while efficiently utilizing the bandwidth.

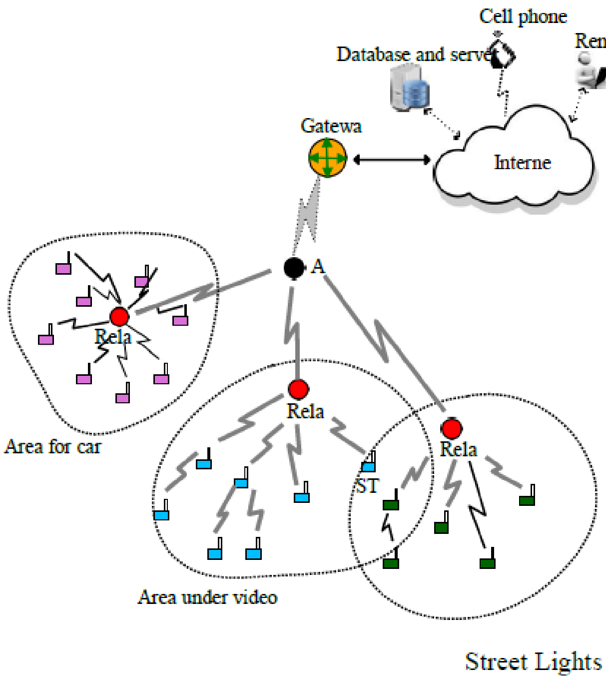

Figure 2.1. IEEE 802.11ah based IoT network spreading over large coverage area

2.2 The Network Topology

The RAP can be connected with the AP using multi-hop distances. Figure 4.3 shows a typical network architecture of IoT using 802.11ah where three IoT networks are con- nected to the Internet. IoT is a combination of sensor and backhaul networks. The overall network can be represented as a set of N(A, R, E) = {B(A, R), T(R, E)}, where *B* and *T* are the back- haul and sensor network respectively, here *A* is the AP node, *R* is the set of RAP nodes(R = R_1, R_2, ..., R_n) and *E* is the set of sensor/actuator nodes (E = E_1, E_2, ..., E_m). *A* takes the responsibility of initialization, synchronization, slot assignment and channel allocation of the whole network. The *R*s are the owner of channels and hold the responsibility of forwarding data from *E*s to *A* and vice versa.

2.3 Node Association

To solve the problem of a huge delay in association procedure, 802.11ah has proposed Centralized Authentication Control (CAC) as well as Distributed Authentication Control (DAC). In CAC, a value called authentication control threshold is set by an AP which is transmitted through the beacon frame. A STA can associate only if the value of it is smaller than the threshold. The DAC scheme divides beacon into different slots of equal duration. It uses two random variables uniformly distributed in beacon and transmission interval, respectively. An authentication request containing the two random variables is sent to the AP using truncated binary exponential backoff. The proposed solutions reduces overall association delay by reducing the number of STAs for sending simultaneous requests.

III. SIMULATION ANALYSIS

The performance of proposed protocol is evaluated through extensive simulations using NS-3. Results are compared with *Traditional* access mechanism of 802.11ah. Further, a sectorization scheme proposed by

Bhandari et al. is compared with the proposed scheme. In SectorGroup, AP broadcasts beacons to the specific locations by utilizing the sectorized beams created with multiple antennas in it. We have analyzed the performance of the proposed protocol as follows:

Association time in proposed Vs. traditional Scheme
Throughput performance of the proposed multi-channel and sectorization schemeDelay performance of the proposed multi-channel and sectorization scheme Analysis of PRR (%) in the proposed load balancing scheme Comparison of the proposed channel access mechanism

3.1 Association Time

The RAPs create different BSSs in the network. Randomly scattered nodes get asso- ciated with the AP or RAP in a distributed manner. It is obvious that the associationtime of the proposed scheme is equal to the time required to associate all STAs from the largest BSS. Total association time for 2000 devices in the proposed protocol is about 37 Seconds, whereas, in traditional 802.11ah, it is 42 Sec- onds. The RAP nodes are further supported with multiple MCSs, where it can choose an MCS with a higher or lower data-rate according to the current requirements of aBSS.

3.2 Throughput in Proposed Vs. Existing Schemes

Along with existing grouping, multi-channel operation and sectorized beacon enhance the throughput performanceup to a great extent. As shown in Figure 4.11a, throughput in the proposed scheme is significantly improved considering 2, 3, and 4 sectors for the same number of chan- nels. Generally, multiple channel operation supported in the scheme can multiply theexiting capacity, but due to the limited memory and processing capabilities of AP and RAP, the achieved throughput in the simulation seems lesser. In the case of SectorGroup scheme with 2 sectors, the throughput performance has improved as comparedto thetraditional scheme.

However, due to the lack of FDM support at AP and multi-channel operation, it shows lesser throughput results than the proposed scheme. We have com- pared the proposed scheme with the traditional scheme considering 2 sectors over a varying number of RAW groups and a larger coverage area. The grouping mechanism in 802.11ah reduces collisions due to contention. For a large number of STAs, through put performance will be better when group size is higher. However, without a proper RAP organization over a larger coverage area, the hidden terminal problem is a major concern. So, along with the RAW grouping for the STAs, our protocol uses location aware sectorized beacon from AP.

To see the throughput performance over normal load conditions, we compare the proposed scheme considering lesser number of STAs in the network. We generate traffic with an interval of 0.5 Sec. Once the saturation point has achieved, the performance of the proposed protocols start deteriorating. The saturation point for the proposed scheme is higher than the existing schemes.

IV. DYNAMIC LOAD BALANCING

We measure the Packet Received Ratio (PRR%) for the traditional scheme with 300Kbps (MCS0, 1MHz) and proposed scheme with 300Kbps (MCS0, 1MHz) and 650Kbps (MCS0, 2MHz). We have introduced varying uplink traffic loads (100-1000Kbps) from different BSS towards AP. The saturation capacity for the traditional scheme is almost 150Kbps, whereas the proposed scheme can carry almost up to 325Kbps. Due to the support of multiple MCSs, at saturation capacity, the RAP in the proposed scheme switches its MCS to another MCSs having a higher data-rate.

4.1 Channel Access Mechanism

Finally, we have measured the efficiency of the BD-TXOP scheme used in the pro- posed protocol as compared to the BlockACK mechanism. In BlockACK, once a list of buffered frames has been sent, the sender node sends a request frame containing the sequence numbers frames. In response to BlockAckReq, a BlockAck frame is further sent by the receiver node. For long-distance and multi-hop networks, high control overhead is another challenge. The BD-TXOP of 802.11ah has solved the issues by not sending an ACK for all received packets, rather the data packet itself is used. Asignificant improvement can be seen in the BD-TXOP-based solution considering bi-directional traffic. We analyze the saturation throughput of the proposed protocol using the Markov Chain model.

V. CONCLUSION

Multi-channel, and load-aware MAC protocol for multi-hop networks. It showed significant performance improvement over the 802.11ah MAC protocol. The proposed protocol achieves a higher success rate, larger coverage range, and lesser delay than 802.11ah. The sectorization scheme increases the network capacity and achieves superior performance over a large-scale distributed network. It can dynamically adjust bandwidth with the use of MCS with a higher data-rate. From the performance results, it is evident that the proposed scheme is a suitable solution for large-scale IoT networks. The proposed distributed association mechanism powered relay placement schemeachieved lesser association time (i.e., 11%) than the traditional fast association scheme. The proposed sectorized network with multiple antennas and four channels improves throughput performance up to almost three times as compared to the traditional and two and half times than the existing scheme. Delay performance also improved up to three and two times as compared to the traditional 802.11ah and SectorGroup scheme respectively. Traffic congestion issues at AP node have been resolved up to a great extent by allowing simultaneous transmission using multiple channels and sectors. Dynamic load balancing and TXOP operation at RAP node increase the efficiencyof the proposed large scale IoT network.

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