A Survey on Medium Access Control Mechanism For NOMA Enabled IoT Systems

Sushma[1], Mr. Aashish Patidar[2]
[1]Dept of Electronics & Communication Engineering
[2]Assistant Professor, Dept of Electronics & Communication Engineering
[1, 2] Vikrant Institute of Tech. & Management Indore (M.P) India

Abstract- *Internet of Things (IoT) has become the buzzword with applications in several domains such as automation, climate monitoring, large scale manufacturing etc. Dynamic spectrum policies combined with software defined radio are powerful means to improve the overall spectral efficiency allowing the development of new wireless services and technologies. Medium Access Control (MAC) protocols exploit sensing stimuli to build up a spectrum opportunity map (cognitive sensing). Available resources are scheduled (dynamic spectrum allocation), improving coexistence between users that belong to heterogeneous systems (dynamic spectrum sharing). Furthermore, MAC protocols may allow cognitive users to vacate selected channels when their quality becomes unacceptable (dynamic spectrum mobility). In this paper, a comprehensive review on MAC protocols for IoT networks along with channel sensing and utilizing the channel state information has been presented with the attributes of each approach.*

Keywords- Cognitive radio, Software Defined Radio (SDR), Cognitive Network, Channel State Information (CSI), Bit Error Rate (BER).

I. INTRODUCTION

The Internet of Things is the concept of connecting any device (so long as it has an on/off switch) to the Internet and to other connected devices. The IoT is a giant network of connected things and people – all of which collect and share data about the way they are used and about the environment around them. The present spectrum authorizing plan is not able to oblige quickly growing demand in wireless communication due to the static spectrum allocation strategies. This allocation prompts increment in spectrum scarcity issue. IoT (CR) technology is a propelled remote radio design which aims to expand spectrum utilization by distinguishing unused and under-used spectrum in rapidly evolving environments. Spectrum sensing is one of the key strategies for IoT which detects the presence of primary client in authorized licensed frequency band utilizing dynamic spectrum assignment policies to utilize unused spectrum. In many areas IoT frameworks coexist with other radio frameworks, utilizing the same spectrum yet without creating undue interference.[1],[3]

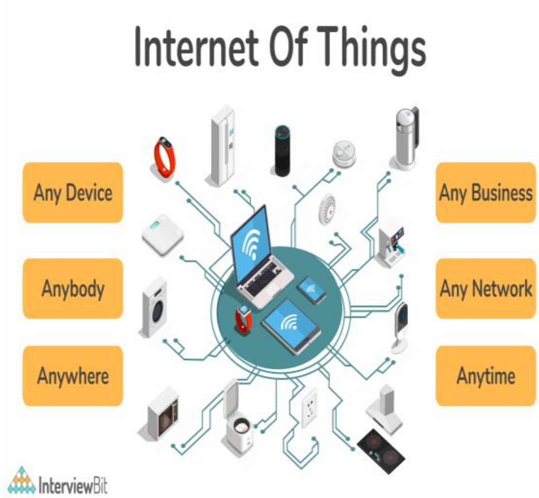

Fig.1 A Typical IoT Environment.

The most simple and easy way to implement sensing technique is energy detection. With IoT being utilized as a part of various applications, the territory of spectrum sensing has become progressively vital. As IoT technology is being utilized to provide a method for utilizing the spectrum all the more productively, spectrum sensing is key to this application. The ability of IoT frameworks to get to spare sections of the radio spectrum, and to continue observing the spectrum to guarantee that the IoT framework does not create any undue interference depends totally on the spectrum sensing components of the framework [4].For the overall framework to work viable and to provide the required change in spectrum efficiency, the IoT spectrum sensing framework must have the capacity to adequately recognize some other transmissions, distinguish what they are and inform the central preparing unit inside the IoT so that the required actions can be taken.

Advantages of IoT

1. Mitigate and solving spectrum access issues.
2. Spectrum utilization improves.
3. Improves wireless networks performance through increased user throughput and system reliability.

4. More adaptability and less co-ordination.

II. MEDIUM ACCESS CONTROL (MAC) PROTOCOL IN IOT NETWORKS

The principal step of spectrum sensing in IoT networks is that it decides the presence of primary user on a band. The IoT has the capacity to impart the result of its detection with other IoTs in the wake of sensing the spectrum. The main objective of spectrum sensing is to discover the spectrum status and activity by periodically sensing the target frequency band. The IoT system examines all level of flexibility (time, frequency and space) to predict spectrum usage. There are a few procedures available for spectrum sensing. Spectrum sensing is a system which figures out if a given frequency band is utilized. A wide range of routines are proposed to recognize the presence of signal transmission and can be utilized to improve the detection probability.

The aim of the spectrum sensing is to decide between two hypotheses which are

$x(t) = w(t)$, H0 **(Primary User absent)**

$x(t) = h * n(t) + w(t)$, H1 **(Primary User present)**

Where x(t) is the signal received by the CR user, n(t) is the transmitted signal of the primary user , w(t) is the AWGN band, h is the amplitude gain of the channel.

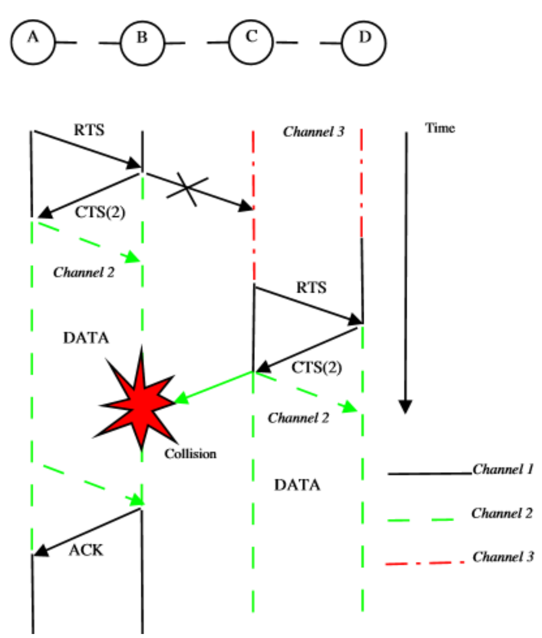

Fig.2 Multichannel collision Problem in MAC

H0 is a null hypothesis, which states that there is no licensed user signal. Energy Detection is a simple detection method. The energy detection is said to be a blind signal detector in light of the fact that it overlooks the structure of the signal. Energy detection is based on the rule that, at the receiving end, the energy of the signal to be detected is computed. It estimates the presence of a signal by comparing the energy received and a known threshold λ derived from the statistics of the noise.

If the frequency response of the system is available, then under such a condition, we possess the Channel State Information (CSI).

III. CHALLENGES IN UTILIZATION OF CSI FOR IOT SYSTEMS

As wireless media are highly random in nature, therefore sensing the spectrum and using the Channel State Information (CSI) to suppress the frequency tones leading to low Signal to Noise Ratio (SNR) is crucial to improve upon the BER performance of the system. Such systems can be efficiently modelled as a Software Defined Radio (SDR).

Problem of BER:A major challenge for any wireless communication system is the frequency selective nature of wireless channels. For multi carrier modulation schemes, frequency selectivity poses a serious problem since different sub carriers are treated by the channel differently. Carriers which belong to the frequency range where the channel gain reduces drastically, undergo heavy attenuation. The attenuation varies with the frequency response of the channel. The result of this phenomenon is variable sub carrier gain or sub carrier strength. While some sub carriers may have satisfactory gain, some may have average gain while others may have extremely low sub carrier gain.

The sub carriers with low sub carrier gain or strength tend to adversely affect the Bit Error Rate of the system, since low strength of the carriers would imply low signal to noise ratio (SNR). This eventually introduces errors and results in non-reliable communication. Therefore it is important to suppress sub carriers with low gain or strength to improve the BER performance of the system.During the fades user experiences a signal outage.Outage probability determines the amount of signal strength which is less below the minimum noise power. So for proper reception outage probability should be as lowas possible. Thus it is important to improve the signal to noise ratio (SNR) for improving system performance.

IV. PREVIOUS WORK

Lai 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 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, proportional fairness transmission rate among different secondary IoT devices, maximum number of accessed secondary IoT devices for each subchannel, and interference power threshold constraint at each primary base station (BS). Numerical simulation results demonstrate that the throughput and fairness for the proposed algorithm are better than that of other resource allocation algorithm significantly.

Soya et al. put forth a really innovative approach that was based on full duplex mode relay selection and it used IoT. As the IoT is an intelligent system of spectrum sensing and relay selection method, it comes with several benefits. The authors actually utilized this idea and merit of the radio network. It was a two way communication and could detect interference very fast and also it helped to enhance the overall functionality of the communication system. It exhibited good performance and provided a lot of flexibility and robust behavior.

Lai et al. researched on the cache based mechanism of the channel state information based system model. It consisted of an added cache that could store useful data for the IoT network to work very well. The CSI was outdated but retained all useful data and features that were important for the system design. The transmission of data was from multiples sources and points. Hence it proved to be a good and efficient approach and also gave fair accuracy.

He et al. proposed a novel mechanism on the concept of cooperative IoT networks and its allied benefits . One application where it was applied is the energy harvesting domain. It really worked well to improve the spectrum efficiency and also the overall communication quality.

The outage possibility was also analyzed and the measures were taken accordingly. It used the primary transmitters to send the signals to multiple receivers and it became a vast cognitive network that could communicate with many signal receivers and senders. Overall it is a good model that worked to improve the spectrum bandwidth very effectively and also the communication was noise and degradation free as it could sense any problem very well and in a robust manner. The system was very reliable and fast.

Liang et al. showed thatIoT helps tremendously to mitigate the situation where the spectrum frequencies are unavailable and there is a deficit of the spectrum for radio communication. This cooperative IoT concept was explored by the authors and they studies on how the efficacy of the spectrum can be increased and overall throughput of the system can be enhanced. The interference between the licensed and ordinary users was also given due importance and the design of the system helped in the relaying and robustness of the entire system.

Nguyen et al. showed that the concept of IoT networks that were based on cooperative half duplex mode. The K relay selection acts as the frontier component for the optimum functionality. The IoT networks provide a lot of benefits to utilize the channel properly and reduce the wastage of the allotted bandwidths. This scheme which is a relay based selection schemes works perfectly well with all other methods that are supposed to go with it. For using the radio spectrum band in a more effective and beneficial manner, the concept of IoT has become prominent. Therefore this method gave really satisfactory outcomes in terms of throughput and channel utilization.

Cao et al. discussed the utilities and advantages of cooperative IoT networking and the communication surrounding it. The improvement in the spectrum utilization and the overall channel usage is of top importance in the radio communication. The relaying type of transmission has also its own role. It helps in amplifying and decoding the signal transmissions easily. So this idea of IoT is gaining prominence in the domain of radio transmission due its added advantages and also the variety of benefits it offers. The energy aware variant of the IoT networks is also gaining a lot of momentum in the communication field. The power allocation and usage is further improved and progresses very well with these resources. This gives a wider range of region to operate upon and also enhances the performance and flexibility of the network and also the communication.

Xu et al. computedenergy efficiency of the cognitive nodes in spectrum sensing process is very important. As the energy potential of each cognitive user is limited, there arises this need to conserve the energy for the radio communication. This study focuses on the energy aware mechanism of the optimal relay selection scheme and also presents a bit error rate constraint. The BER is a vital performance metric that is supervised in this work. Both the spectrum sensing and cooperative communication of the IoT consumes considerable amount of energy.

Yang. et al. proposed study on the device to device communications which are fifth generation. It discussed about the various methods, challenges and future scope of the 5G D2D networks. The increasing prevalence of high speed communication services and the digitally savvy world has made it mandatory to have a high end communication scheme. 3G and 4G have already been used extensively over the last few years. With development in the communication sector and technical advancement, the device to device communications have also undergone transformation. This work highlights the merits of the D2D networks based on 5G and also how it is an improved technology.

V. MATHEMATICAL MODELLING FOR BER AND OUTAGE OF A IOT SYSTEM

Outage: Let a cellular system is indicated for $\Phi = \{C, D\}$, C is cellular communication and D is D2D communication. It is also assumed that the distribution of device nodes of system follows a stationary Poisson point process (PPP) with density of λ_D in the finite two-dimensional plane. The channel model includes path loss and Rayleigh fading. Therefore, the power of the node i received from j can be expressed as: $P_i\delta_{ij}|X_{ij}|^{-\eta}$, $i, j\epsilon\Phi$, P_i is the power of node i, δ_{ij} is the Rayleigh fading indexbetween i and j, and it has an exponential distribution with unitmean, X_{ij} is the distance between node i and j, η is thepath loss exponent.Signal to interference plus noise ratio at the receiver k is given as:

$$\mathrm{SINR_k} = \frac{P_k\delta_{k0}R_k^{-\eta}}{\sum_{j\epsilon\Phi}\sum_{X_{ji}\,\epsilon\pi_j} P_j\delta_{ji}|X_{ji}|^{-\eta} + N_0}$$

where δ_{ji} is the fading factor on the power transmitted from the desired transmitter to the receiver, N_0 is the thermal noise power, spectrum sharing systems are interference limited systems, so the thermal noise is negligible in regimes of interest. So the SIR can be used instead of SINR, which allows simplification to:

$$\mathrm{SIR_k} = \frac{\delta_{k0}R_k^{-\eta}}{I_k}$$

$I_k = \sum_{j\epsilon\Phi} I_{kj}$ Where I_{kj} is the sum of the power normalized interference from transmitting nodes of system j to the receiver of system k, which is defined as $I_{kj} = \left(\frac{P_i}{P_k}\right)\sum_{X_{JI}\epsilon\pi_j}\delta_{ji}|X_{ji}|^{-\eta}$, for QOS of system k (D2D or cellular users), SIR required to meet a certain threshold: $\mathrm{SIR_k} \geq V_k$, where V_k is target SIR, then the probability of successful transmission can be defined as:

$$\begin{aligned} P(\mathrm{SIR_k} > V_k) &= P\left(\delta_{k0} \geq V_k R_k^{\eta} I_k\right) \\ &= \int_0^{\infty} P\{\delta_{k0} \geq V_k R_k^{\eta} I_k\} f_{Ik}(I)\, dI \\ &= \psi_{Ik}\left(V_k R_k^{\eta}\right) \end{aligned}$$

δ_{k0}Is exponentially distributed, then $\psi_{Ik}(V_kR_k^{\eta})$ is the Laplace transform of $f_{Ik}(I)$, which can expressed for $E[e^{-I_k\eta}]$,

$I_k = \sum_{j\epsilon\Phi} I_{kj}$, the interference I_{kj} is independent to each other,

$$E[e^{-I_k\eta}] = \prod_{j\epsilon\phi} E[e^{-I_k\eta}],$$

then the probability ofsuccessful transmission can be changed to

$$(V_kR_k^{\eta}) = \prod_{j\epsilon\Phi} \psi_{Ikj}(V_kR_k^{\eta})$$

Especially, when the interferingnodes are Poisson pointdistributed:

$$\begin{aligned} \psi_{Ij}(V_kR_k^{\eta}) &= \exp\left\{-\lambda_j \int_{R^2}^{1} 1\, E\left[e^{-V_kR_k^{\eta}\delta|X|^{-\eta}}\right] dx\right\} \\ &= \exp\left\{-\lambda_j \int_{R^2}^{1} \frac{V_kR_k^{\eta}\delta|X|^{-\eta}}{1 + V_kR_k^{\eta}\delta|X|^{-\eta}}\, dx\right\} \\ &= \exp\left\{-C_\alpha R_k^2 V_k^{2/\eta}\gamma_{kj}\lambda_j\right\} \end{aligned}$$

$\gamma_{kj} = \left(\frac{P_j}{P_k}\right)^{2/\eta}$ Is power ratio, where P_j and P_k are power of system j and k,

$C_\eta = (2\pi/\eta)\Gamma(2/\eta)\Gamma(1 - 2/\eta)$, where $\Gamma(x) = \int_0^{\infty} y^{x-1}e^{-y}\, dy$ is a gamma function.

Therefore, success transmission probability of system k is:

$$P(\mathrm{SIR_k} \geq V_k) = \exp\left\{-K_k \sum_{j\epsilon\Phi} \gamma_{kj}\lambda_j\right\}$$

here, $K_k = C_k R_k^2 V_k^{2/\eta}$.

Thus the outage probability of D2D receiver is

$$q(\lambda) = \exp\left\{-\frac{2\pi^2}{\eta\sin\left(\frac{2\pi}{\eta}\right)} R_k^2 V_k^{2/\eta}\lambda\right\}$$

BER: We know that probability of error is given as:

$$P_e = P(0)P(1/0) + P(1)P(0/1)$$

Provided that system is assumed to be affected only by white noise than

$P(1/0) = P(0/1)$

So, $P_e = P(1/0)[P(0) + P(1)]$(4.27)

$$P_e = P(1/0) \text{ Or } P(0/1)$$

$$P_e = \int_{v_{th}}^{\infty} f(z/0)dz$$

$$= \int_{v_{th}}^{\infty} \frac{1}{\sqrt{2\pi\sigma_{n_0}^2}} e^{\left(\frac{-(z-a_z)^2}{\sigma_{n_0}^2}\right)} dz$$

Assume $\frac{z-a_z}{\sigma_{n_0}}$ = y, $z - a_z$ = y.σ_{n_0}

Differentiating above equation we get,

$d_z = \sigma_{n_0} d_y$

For z = ∞, y$\rightarrow \infty$ and z = V_{th}, y = (V_{th} – a_2)/ σ_{n_0}

$$y = \frac{\frac{a_1 + a_2}{2} - a_2}{\sigma_{n_0}}$$

$$= \frac{a_1 - a_2}{2\sigma_{n_0}}$$

We know that Q-function,

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^{\infty} e^{\frac{-y^2}{2}} dy$$

Where y = a dummy variable.

Thus, probability of error can be expressed as

$$P_e = \frac{1}{\sqrt{2\pi\sigma_{n_0}^2}} \int_{\frac{a_1-a_2}{2\sigma_{n_0}}}^{\infty} e^{\left(-y^2/2\right)} \sigma_{n_0} dy$$

In terms of Q-function, probability of error can be expressed as

$$P_e = Q\left[\frac{a_1 - a_2}{2\sigma_{n_0}}\right]$$

In case of matched filter, P_e is given as

$$P_e = Q\left[\sqrt{\frac{(a_1 - a_2)^2}{4\sigma_{n_0}^2}}\right]$$

When more than one signal is transferred through the matched filter then h (t) = x(τ-t) where x(t) =x_1 (t)- x_2 (t) then $\frac{(a_1-a_2)^2}{\sigma_{n_0}^2}$ corresponds to its maximum possible of $\frac{E_D}{\frac{N_0}{2}}$, so that P_e corresponds to its minimum possible.

$$P_e = Q\left[\sqrt{\frac{1}{4}\frac{E_d}{\left(\frac{N_0}{2}\right)}}\right]$$

Where $E_D$is energy of x (t).Thus in terms of signal power to noise power, P_e can beexpressed as $P_e = Q\left[\sqrt{\frac{S}{N}}\right]$

Where S = signal power = E_D/4, N = noise power = $N_0 \times$ Band width

VI. CONCLUSION

With the advent of IoT networks, and with several more applications in wide area networks and metropolitan area networks, it is becoming even more challenging to render reliable data transfer mechanisms. The necessity to accommodate more data in the network has resulted in over burdening of the existing systems with high data traffic. The major concern in this regard remains the reliability with which data can be shared among the nodes in the network. A study of previously existing medium access control (MAC) protocols indicate the fact that relaying is a common technique used for large area networks and data is routed through paths containing several nodes. The paper presents a comprehensive review on cognitive networks and its evaluation metrics.

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