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QoS Aware and Green Hybrid Access Network

P. Maheswaravenkatesh[1,*], *A. Sivanantha Raja*[2], *T. Jayasankar*[1] *and K. Vinothkumar*[3]

[1] Department of ECE, Anna University, BIT Campus, Tiruchirappalli, Tamilnadu, India
[2] Department of ECE, A.C. College of Engineering and Technology, Karaikudi, Tamilnadu, India
[3] Department of ECE, J.J. College of Engineering and Technology, Tiruchirappalli, Tamilnadu, India

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Abstract: Energy consumption of ICT (Information and communication Technology) is emerging with tremendous challenges which are prevailing throughout the world. One among them is energy conservation which plays a vital role in telecommunication networks. The access network, which is the last mile of telecommunication network plays the dominant role of energy consumption. So, effective strategies to reduce energy consumption in access systems can foremost savings in the Internet energy consumption. We set a goal to decrease energy consumption in access networks without diluting the Quality of Service (QoS). To develop the “Green Hybrid Wireless Optical Broadband Access Network” focusing on a feasible implementation of a sleep mode in Optical Network Unit(ONU) at passive optical networks (PON). Wireless Optical Broad Band Access Network(WOBAN) is a novel hybrid access concept combining the high capacity Optical backhaul (PON) with a wireless front end, thus providing very high throughput in a cost-effective manner. We propose a strategy to improve the energy efficiency of WOBAN. The proposal consists of increasing the number of sleep cycles to improve energy conservation in ONUs with a fast wakeup capability. It can increase the number of sleep cycles. To implement this proposal, an algorithm is designed to improve the energy efficiency while ensuring QoS, keeping delays under a threshold and setting the ONU in sleep mode

Keywords: Information and Communication Technology, Passive Optical Network, Broadband Access Network, Optical Network Unit, Quality of Service.

1 Introduction

ICT along with the internet enhances our lifestyle needs by transforming our society with environment–approachable technologies. As a result there is an enormous growth of Internet traffic nowadays and it will continue to grow at a faster rate in the forthcoming years. Hence it is essential to produce energy-efficient (Green) system resolutions for supportable ICT development

1.1 Status of Optical Networks in Future Energy Scalability

To Study the comparison of power consumption in each user uses several networking techniques. The technologies contain passive optical network (PON), Point to point optical network (ptp), wireless access via the Universal Mobile Telecommunication System (UMTS) and Worldwide interoperability for Microwave Access (WiMAX), traditional digital subscriber lines (DSL), hybrid fiber coaxial network (HFC), and copper cables used in fiber-to-the-node technology (FTTN).

Energy consumption of each access nets are analyzed based on three components such as customer locations equipment (usually a modem). The wireless techniques UMTS and WIMAX consumes more power while the optical communication methods. The optical systems have been recognized to be the greatest energy efficient communication platform available.

1.2 Green PON

In telecommunications network a passive optical network (PON) is uses point-to-multipoint fiber to the locations. Passive optical splitters are used to allow a single optical fiber to serve multiple locations. A PON entails of an Optical Line Terminal (OLT) at the facility provider’s central office and a number of optical network units (ONUs) near end users [1].

* Corresponding author e-mail: maheshwaravenkatesh@gmail.com

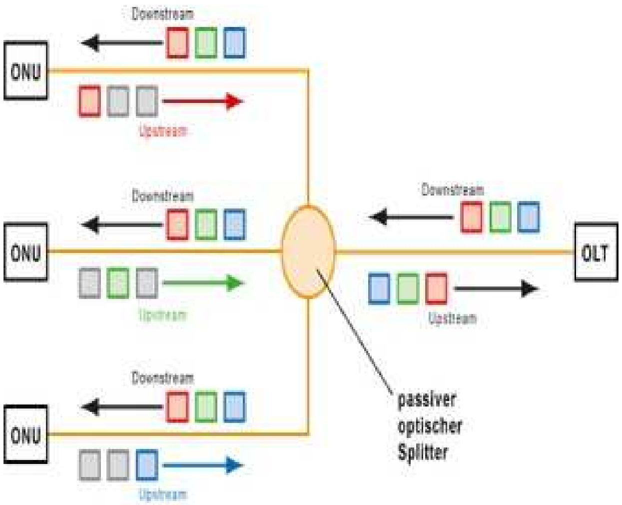

Fig. 1: PON System.

A PON diminishes the quantity of fiber and central office equipment essential related with point-to-point architectures. A PON takes advantage of Wavelength Division Multiplexing (WDM), using one wavelength for downlink traffic and additional for upstream traffic on a single non-zero dispersion-shifted fiber shown in Fig. 1.

PONs, have some different benefits. They are effective, in that individual fiber optic feature can assist up towards 32 users. PONs have a low setting up and maintenance rate comparative to dynamic optical networks. Because there are limited affecting or electrical parts, the only fewer that can go wrong in PON.

Since Active Optical Networks require at least one switch aggregator, which consumes power for every 48 subscribers, they are less reliable than a passive optical network.

1.3 Approach for Implementing Energy Efficiency in PONs

- Physical layer solutions target Physical layer of PON architectures deprived of modifying the higher layer protocols.
  - Device oriented solutions reduce energy consumption of physical devices [2].
  - Services oriented solutions improve the performance of the facilities provided by the physical layer to permit upper layer resolutions [3].
- Data link solutions layer target the data link layer of IEEE 802.3 architecture (i.e MAC layer) or the transmission coverage (TC) layer in GPON [4].
- Hybrid solutions are the ones that combine physical and data link layer resolutions to decrease energy consumption. (e.g sleep mode and adaptive link rate).

2 Access network

There exist several access technologies digital subscriber line (xDSL), cable Modem (CM), wireless and cellular networks, fiber-to-the-x (FTTx), wireless-optical broadband access network (WOBAN), etc. Since customers need bandwidth-intensive services, upcoming access systems should support higher data rates.

The best data rates providing by access technologies such as xDSL, wireless, and cellular networks resolve quickly influence a satiety point in sufficient imminent Internet demands. FTTx methodologies can support larger data rates but unaffordable charge.

Cutting-edge development of hybrid wireless-optical technologies, designed at higher data rate and video applications is being observed. WOBAN—a new cross access network standard association of high-capacity optical backhaul with a wireless front-end can offer very high data rates in a affordable rate.

The rate for each byte of traffic in access technologies is dropping over time, construction of broadband access affordable to more users. Though, there is important wastage of electricity (several TWh/year) in the Internet due to ineffective network and system strategy. A decent share of this energy is spent in idle network elements.

There are two strategies defined to improve network application by using methods such as shutting down the idle network elements, by using energy-aware routing, etc. These strategies can be categorized as energy aware network design and energy aware protocol strategy.

Coalescing wired and wireless access knowledges in a cross architecture to offer broadband access, as in WOBAN, not only provides a cost-effective solution, but also allows excessive probabilities for energy savings.

2.1 WOBAN ARCHITECTURE

WOBAN is a innovative access network architecture through an optimum combination of an optical backbone network (e.g., a passive optical network (PON)) and a wireless front-end (e.g., WiFi and/or WiMAX).

In WOBAN, a PON section starts from the optical line terminal (OLT) next to the control Office and terminates by multiple optical network units (ONU). Several wireless routers form the front-end of WOBAN. A certain set of these routers are defined as gateways [5].

OLTs are comparatively modest network elements from an architectural perception. There are three purposeful elements inside an OLT namely transponders, wavelength multiplexers and optionally optical amplifiers.

The transponder can enhance added overhead for the determinations of network management. It may optionally contain forward error correction (FEC), predominantly for signals at 10 Gb/s and higher data rates. The wavelengths produced in the transponder characteristically adapt to morals set by the International Telecommunication Union (ITU).

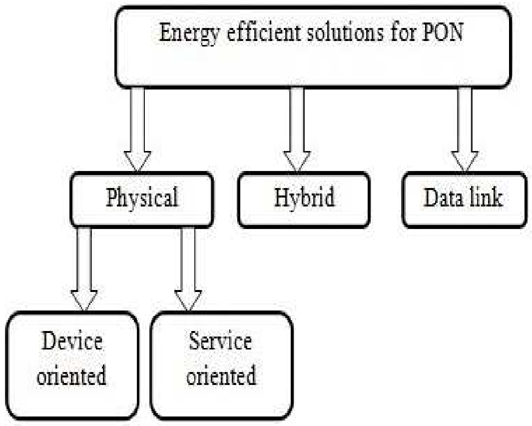

Fig. 2: Various approaches for implementing energy efficiency.

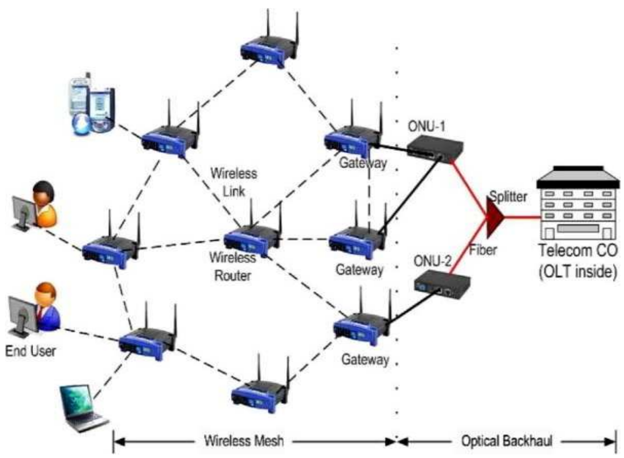

Fig. 3: A fiber–wireless access architecture.

Transponders naturally found the majority of the cost, footprint, and power consumption in an OLT. Hence, reducing the number of transponders supports minimize both the cost and the size of the equipment deployed

The signal approaching a transponder is multiplexed through other signals by dissimilar wavelengths using a wavelength multiplexed feed in to a fiber. Any of the multiplexing technologies such as arrayed wavelength gratings, dielectric thin–film filters, or fiber Bragg gratings can be used for this determination.

A nominated established these routers are named as gateways. The proposal of WOBAN is basically a multi hop wireless mesh network (WMN) through numerous wireless routers also partial no of gateways. Those gateways are associated with the passive optical network through the ONUs. To each ONU provision numerous wireless gateways. End-users (both mobile and stationary) attach to WOBAN over the wireless routers.

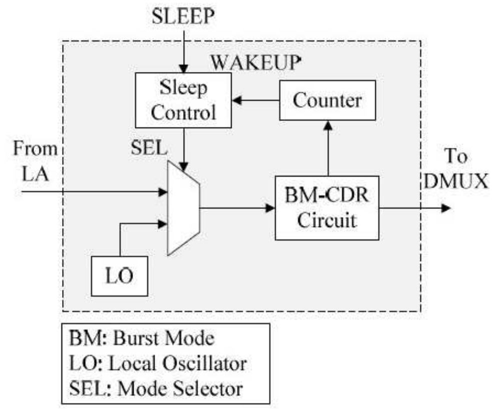

Fig. 4: ONU Receiver Architecture.

Universal WOBAN, once an user needs to communicate a packet, it directs the packet to its adjacent wireless router. The wireless router to distribute the packet(s) to nearest of the gateways. Therefore, in the upstream direction of the wireless mesh, WOBAN remains an *anycast* system. The gateway can then direct the packet towards the ONU connected to it. In the optical backhaul (from ONUs to OLT), WOBAN is a shared-medium access network where ONUs deal with shared forward channel in a time division multiplexing.

The optical backend in the reverse downstream is a *broadcast* network wherever packets are broadcasted to all the ONUs. Only the destination ONU retains the packet, whereas others discard them. But, in the downstream direction from the wireless gateways, WOBAN is a *unicast* network, meanwhile a gateway will send the downstream packets in the direction of the specified destination routers. In [6]

In Wi-Fi access networks the end operators advance network connectivity once linking to wireless routers shown in Fig. 3. The wireless routers onward packets adjacent gateways wherever connectivity to the optical backhaul is provided. Next to the PON the ONUs contends used for upstream bandwidth, using time division multiplexing (TDM), though the downstream traffic is broadcasted to all the ONUs. Individual ONU will formerly reject any traffic not intended used for it.

2.2 ONU Receiver Architecture

At present, entire ONUs is kept active to unceasingly accept downstream data from optical line Terminal (OLT) even once the data is not intended to other ONUs.

This outcomes in unbelievable energy waste when ONU is not receiving suitable data. Instead the ONUs are would be set into the sleep mode rendering to their real time traffic [7]. Current ONU would take a twosome of ms to improve clock information after transitioning from sleep mode. A Generic Sleep mode ONU Receiver

Architecture that allows ONU to changeover from sleep mode to active mode in less than 64 ns by Fast clock and data retrieval circuit is shown in Fig. 4.

2.3 Energy Saving Performance Evaluation

2.3.1 Limitation of Delay

To deliver QoS assurances, the normal packet delay determination be kept under the threshold Δ_{th},

$$\sum_{v \in V(OLT)} \Delta_v^s(s) \leq \Delta^{th} \forall_s \in \rho \tag{1}$$

Presuming that the portion of time that an ONU v is awake is provided by $\frac{\gamma_v}{C_v}$, wherein $C_v = C_o$ according to whether it refers to an ONU, as well as presuming a Poisson model is used for traffic arrivals, the average packet delay is scheduling $S \in \rho$ remains utilized at node $v \in \rho$, represented by the equation $\sum_{v \in V(OLT)} \Delta_v^s(s)$.

If we assume Poisson modal for traffic arrivals, the average packet delay if sleep mode is not scheduled is given by Eq. (1) [8].

$$\Delta_v^s(s) = \frac{1}{C_v - \gamma_v} \quad \text{if } s = 0 \tag{2}$$

If sleep mode is scheduled, then the average packet delay will be

$$\Delta_v^s(s) = \frac{1}{C_v - \gamma_v} + \frac{\gamma_v}{C_v} \frac{C_v - \gamma_v}{C_v} \tag{3}$$

For $s = 0$ (at all times awake mode) the delay resolve the average packet delay related with Poisson arrivals, from queuing model. For $s \neq 0$ one must consider that packets may arrive during awake and sleep periods. Once devices are in standby/sleep, besides the average packet delay for Poisson arrivals, a delay associated with the fact that packets will be line up, and transmitted later the wake-up method, essential to be added.

This is captured by second term in the above equation. The final ones replicate the statistic that additional sleep periods (and, therefore, shorter sleep periods) lead to less packets accumulated in queues [9].

The energy spent by an ONU specified some observation period, could be originate as the sum of energy consumed in active mode desirable that in sleep mode [10, 11].

$$E_{\text{ONU}} = T_{\text{active}} P_{\text{active}} + T_{\text{sleep}} P_{\text{sleep}} \tag{4}$$

where

$$T_{\text{active}} = 2\text{ ms} + T_{\text{overhead}} \tag{5}$$

$$T_{\text{sleep}} = T_{\text{cycle}} - T_{\text{active}} \tag{6}$$

For $S = 1$:
$E_{\text{ONU}} = T_{\text{active}} P_{\text{active}} + T_{\text{sleep}} P_{\text{sleep}}$
$T_{\text{active}} = 2\text{ ms} + T_{\text{overhead}}$ where T_{overhead} is 125μs
$T_{\text{sleep}} = T_{\text{cycle}} - T_{\text{active}}$ where T_{sleep} is 16 ms
and T_{active} is 2.125 ms
$E_{\text{ONU}} = 0.025$ W
For $S = 2$:
$T_{\text{active}} = 2\text{ ms} + T_{\text{overhead}} s(i)$
$T_{\text{active}} = 4.25$ ms
$T_{\text{sleep}} = T_{\text{cycle}} - T_{\text{active}} = 0.01175$
$E_{\text{ONU}} = 0.0314$ W
For $S = 3$:
$T_{\text{active}} = 2\text{ ms} + T_{\text{overhead}} s(i)$
$T_{\text{active}} = (2\text{ ms} + 125 \times 10^{-3})3 = 6.375$
$T_{\text{sleep}} = T_{\text{cycle}} - T_{\text{active}} = 9.625$ ms
$E_{\text{ONU}} = 0.03682$ W

Cycle time denotes the period, within which all ONUs is surveyed and complete upstream and downstream communication.

After ONU wakes up after the sleep mode, there is an overhead time window (T_{overhead}) for improving the OLT clock and recovering network synchronization.

2.4 Algorithm

Step 1: Initialize the packet size (p), transfer capacity of ONU(cn), Delay threshold(dth).

Step 2: Calculate the byte time for ONUs–64ns / (1/cn*p).

Step 3: Get number of nodes.

Step 4: Get the current working load and full capacity of nodes.

Step 5: Calculate the delay threshold using the Poisson process.

Step 6: Select minimum S value so that satisfies the following Condition, delay threshold $>$ calculated delay.

Step 7: Per the delay encountered,
if the delay conditions become true, then,
assign S = 1,
else if the delay conditions become true
assign S = 2, S = 3 and so on

Step 8: Calculate corresponding sleep time, active time and reduced power consumption for each case.

Step 9: else, if the conditions are not true (i.e the calculated delay exceeds the delay threshold), then that node cannot be put into the sleep mode.

3 Results and discussion

The proposed algorithm is tested by applying for various workload in ONU, the delay and corresponding energy efficiency is measured in existing and proposed method in selection of proper S value. It shown in Tables 1 and 2.

The above algorithm, programs have been developed for Optical network Unit and validated using MATLAB software. The screenshots are provided below. Fig. 5

Table 1: Sleep Mode Scheduling For ONU (Existing Method).

Working load(%)	*S* value	Delay in sec	Energy consumed(%)	Reduced power(%)
5	1	0.047504	23.5116	76.4883
10	1	0.090044	27.5376	72.4623
15	2	0.063797	31.5687	68.4312
20	2	0.080050	35.5687	64.4052
25	2	0.093803	39.6211	60.37886
30	3	0.070057	43.6818	56.3481
35	3	0.075895	47.6177	52.3722
40	3	0.080067	51.7037	48.2962
45	3	0.082573	55.7297	44.2702
50	3	0.083413	59.7566	40.2433
55	3	0.082589	63.7816	36.2183
60	3	0.080100	67.8076	32.1923
65	3	0.075945	71.8336	28.1663
70	3	0.070133	75.8596	24.1403
75	2	0.093910	79.8822	20.1177
80	2	0.080200	83.9064	16.0935
85	2	0.064029	87.9323	12.0676
90	1	0.090400	91.95532	08.6467
95	1	0.00483	95.9791	04.0208

Table 2: Sleep mode Scheduling for ONU (Proposed method)

Working load(%)	*S* value	Delay in sec	Energy consumed(%)	Reduced power(%)
5	1	0.0156	05.674	94.326
10	1	0.0297	10.674	89.326
15	2	0.0425	15.816	84.184
20	2	0.0528	20.816	79.184
25	2	0.0618	25.816	74.184
30	3	0.0693	30.957	69.043
35	3	0.0750	35.958	64.042
40	3	0.0792	40.958	59.042
45	3	0.0810	45.958	54.042
50	3	0.0825	50.958	49.042
55	3	0.0816	55.958	44.042
60	3	0.0792	60.958	39.042
65	3	0.0750	65.958	34.042
70	3	0.0693	70.958	29.042
75	2	0.0618	75.816	24.184
80	2	0.0528	80.816	19.184
85	2	0.0421	85.816	14.184
90	1	0.0297	90.674	9.3260
95	1	0.0157	95.674	4.3260

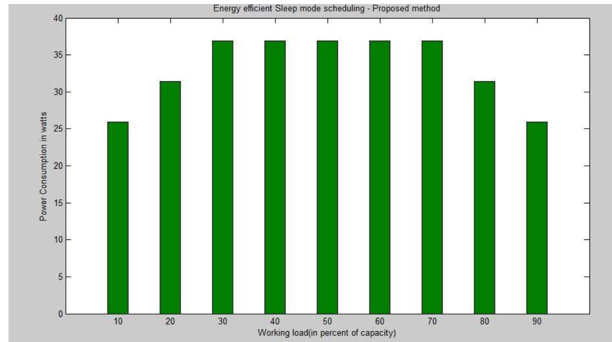

Fig. 5: Power Consumption sleep mode Scheduling for ONU.

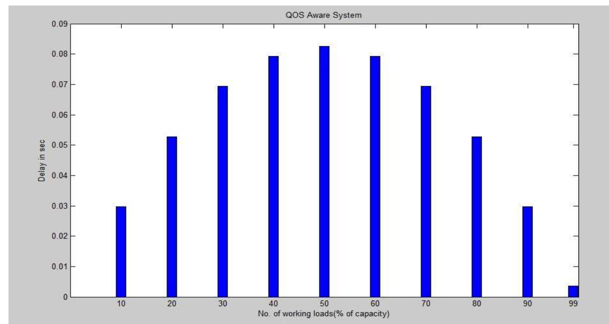

Fig. 6: QoS Aware System.

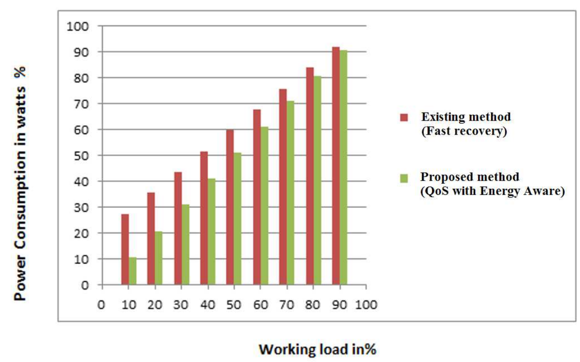

Fig. 7: Power Consumption Sleep Mode Scheduling for ONU.

shows the Power Consumption sleep mode Scheduling for ONU in different workloads.

The above result (Fig. 6) ensures Quality of Service. Keeping the delay under the threshold the nodes are set into the sleep mode and the power consumed by the ONU for various working loads are depicted in Fig. 7 shows the performance comparison.

From the above graph shown the power consumption for the QoS with energy aware sleep mode scheduling is better than fast recovery scheduling method. The proposed algorithm maintain the QoS with higher energy efficiency up to 80% workload of the ONU.

4 Conclusion

We provided for models for assessing the power consumption and delay of FiWi access network. Then we applied mathematical models for energy saving with QoS aware. Our result indicate that allowing no of sleep cycles in the ONU part would reduce power consumption by up to 50% with respect to delay aware in FiWi access network. The algorithm showed to be computationally competent and scalable. Hence, the planned approach can be used for scheduling and strategy of QoS-aware green hybrid access networks.

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P. Maheswaravenkatesh graduated in Electronic and Communication Engineering from the University of Madurai Kamaraj, India, in 1998. In 1999, he joined the Radiant Software Private Ltd. He received a Master degrees Applied Electronics in 2004 from the Anna University, Chennai. From 2005 to 2009, he was an Assistant Professor in the Department of Electronic and Communication Engineering of K.L.N. College of IT, Madurai. Since 2009, he has been an Assistant Professor in the Anna University Chennai, BIT Campus Trichy. He is a member of IEI, ISTE. He has participated in several International and National level conferences and workshops. He has published around 12 papers in the reputed international journals and more than 15 papers in the international and national conferences. His research activities are focused on Optical Communication Networks, Wireless Communication and Signal Processing.

A. Sivanantha Raja has finished his B.E. in Electronics and Communication Engineering, M.E. in Microwave and Optical Communi-cation Engineering and Ph.D. in Biomedical Applications. Currently he is working as an associate professor in A. C. College of Engineering and Technology, Karaikudi (An Autonomous Government Engineer-ing College), Tamilnadu, India and he is guiding 10 Ph.D. scholars, 2 M.S. scholars, and he guided more than 75 M.E. thesis in the field of optical communication networks, photonic crystal-based component devices and biomedical applications. He has published around 55 papers in the reputed international journals and more than 75 papers in the international and national conferences and contributed one book chapter. His areas of interest are Optical communication, Nonlinear optics, Photonic crystals, and RF circuits.

T. Jayasankar received the B.E. degree in Electronics and Communication Engineering from Bharathiyar University, Coimbatore in 2001 and M.E. degree at Madurai Kamaraj University, Madurai in 2003 and Ph.D. in Speech Processing at Anna University Chennai 2017. At present, he is an Assistant Professor in the Electronics and Communication Engineering department, University College of Engineering, Anna University, Bharathidasan Institute of Technology Campus, Tiruchirappalli Tamilnadu, India. He is a member of IEI, ISTE. He has been a lecturer at graduate and post-graduate level and has participated in a number of International and National level conferences and workshops. He has published around 25 papers in the reputed international journals and more than 15 papers in the international and national conferences and contributed one book chapter. His main interest is currently speech synthesis, speech and image processing and wireless networks.

K. Vinoth Kumar Working as a Assistant Professor (Senior Grade) in J.J. College of Engineering and Technology, Trichirappalli, Tamil Nadu,India.He received the Bachelor's degree in Electronics and Communication Engineering from the Kurinji College of engineering and technology, Manapparai, Tamil Nadu, India, in 2009. He received the Master's degree in Applied Electronics from the J.J College of engineering and technology, Trichirappalli, Tamil Nadu, India, in 2011. He received the Ph.D in Karpagam University Coimbatore, Tamil Nadu, India in 2017. He is a member in Universal Association of Computer and Electronics Engineer (UACEE) and member in International Association of Engineer (IAENG). He published more than ten international journals. His research interest includes wireless communication, Mobile Ad hoc networks, and Sensor Networks and Communication networks. He published 2 science indexed journals and 5 Scopus Indexed journals.