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Optimized energy ingestion in IoT enabled sensor nodes: a survey

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ABSTRACT

This survey reviews the energy effective mechanisms that direct the Internet of Thing (IoT) evolution while examining the specific areas for energy optimization in wireless sensor nodes. This paper emphasizes the progress in evolving energy techniques which target to reform the skeleton of IoT. Energy dissipation of an IoT sensor node on its layer-based structure is discussed in the paper. An energy saving technique is surveyed under the relationship of IoT and the cognitive radio networks in mobility aspects. In addition, a feedback based energy profiling and reduction of control frame size techniques are discussed that in what manners do they help to reduce energy dissipation. In this paper, we focused on the need of energy optimization for sensor nodes by considering the heterogeneous nature of IoT node for the future needs.

Keywords: cognitive radio networks; internet of things; wireless sensor networks; energy efficiency; security; routing;

1. INTRODUCTION

The Internet of Things (IoT) is a network of heterogeneous communication nodes connected with each other through internet providing and exchanging data sensed and collected from other nodes. Smart homes, smart factories, smart cities and smart grids are the major application areas where IoT is playing a vital role [1]. Numerous sensor nodes are used in these types of environments in which most of the nodes are wireless and battery operated. Every node in that network is deployed for some specific purpose and is a foothold. Since every node is battery operated, therefore its energy consumption is a noticeable point. If any node is compromised due to low energy, it could cause a big decision failure for the network. As the majority of nodes are wireless and are using free ISM band and there are other devices too, which are using the free ISM band consequently when there is a huge number of nodes communicating at same channel, they would interfere each other [2]. This interference would lead to higher packet drop ratio and a flooding of control packets, so retransmissions would take part. In addition, by transmitting the same information multiple times would lead to higher power consumption in vain.

Cognitive radio (CR) is an option, which can be used to challenge this issue. CR would not only confront this issue but would also make IoT network more reliable regarding connectivity communication and would also address bandwidth availability issues. In this paper, we have discussed the energy dissipation of an IoT sensor node on its layer-based structure. Different techniques used under different layers are considered. For the futuristic approach, some energy saving techniques are discussed under the relationship of IoT and the cognitive radio networks in mobility aspects, a feedback based energy profiling and reduction of control frame size is discussed that in what manners do they help to reduce energy dissipation.

1.1 Cognitive radios

Cognitive radio networks (CRN) are composed of wireless cognitive radio nodes, which can intelligently scan the radio-frequency spectrum and identify available communication channels which are in use and which are not [3]. Donor network whose spectrum is being scanned for vacant channels is the primary network so users are the primary users (PU) and the opportunist network is cognitive radio network so users are the secondary users (SU). SUs switches itself instantaneously into unoccupied channels while avoiding the occupied ones. This optimizes the use of available radio-frequency spectrum while minimizing interference to other users [4, 5]. In November 2008, the federal communication commission (FCC) announced that vacant part of the radio-frequency spectrum (spectrum white spaces) should make available to be used by the public [6]. And the devices which can use the white spaces must be ensured to implement interference prevention, secure allocation of white spaces and geolocation identification techniques [7].

Cognitive radio is a hybrid technology, a CR can scan and sense and analyze neighboring nodes which are active or inactive, their identification and authorization, determination of geographic locations of nodes, identifies the channel opportunity to switch on, spectrum management and handoffs, spectrum sharing and allocation, spectrum mobility, multiple adjustments of power and modulation techniques, encryption and decryption of signals [8].

1.1.1 Spectrum sensing

The major part of CR is its spectrum sensing capabilities, there are three main methods to sense a spectrum, how an SU will access the licensed spectrum.

Opportunistic spectrum access (OSA): the SUs access the frequency channel if and only if it has been detected unused by the PU [9].

Spectrum Sharing (SS): an underlying scheme, SUs, and PUs coexist but SUs are on a condition to protect PUs and avoid harmful interferences [10].

A hybrid approach introduced to increase the throughput of the previously mentioned schemes. SUs sense for the active and idle frequency channels and reconfigure themselves accordingly by protecting PUs from harmful interferences [11].

Figure 1 shows the different spectrum sensing techniques.

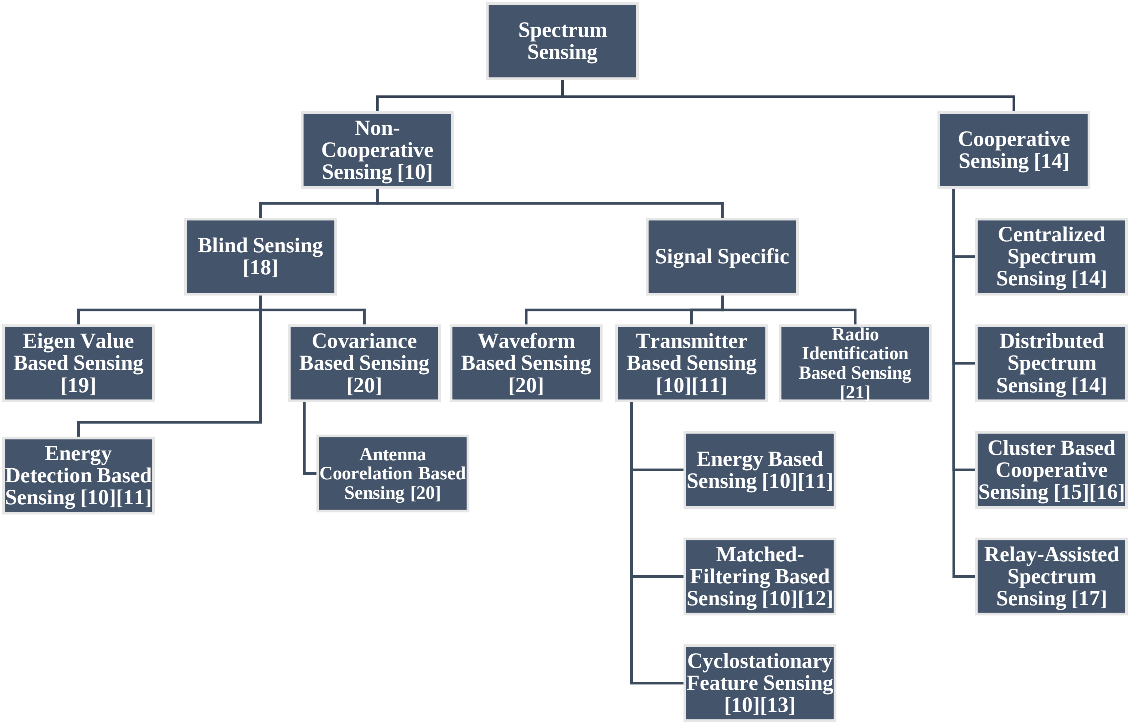

Figure. 1 Spectrum Sensing Techniques

Whatever the approach is, the whole CR system is relying on spectrum sensing. If this is not done efficiently and accurately it could not be guaranteed that it would work. Spectrum sensing techniques can be classified further into different categories as shown in Fig. 1. Every category has its own kind of features and application area [12-23]. Cognitive radios are setting up new standards and opening new horizons for emerging technologies like defense, health monitoring, satellite communications, public safety, smart technologies, internet of things and next-generation technologies. Many wireless devices in small-cell configurations communicate on same spectrum parameters, due to this phenomenon the network nodes face a lot of interference from the neighboring nodes. This interference between neighboring channels can be avoided by using CR technology, because every node would be aware of its neighboring channel usage so will avoid using the same channel to communicate [24]. CRNs can also be implemented to increase network capacity as well as for higher throughput. Internet of Things is an emerging technology and is anticipated to connect thousands of billions of assorted devices/sensors/objects through internet [25].

1.2 Cognitive radios and internet of things

IoT is a new and evolving archetype that integrates numerous technologies, including wired and wireless sensors, mobile phones, smart devices, and actuators along with intelligent protocols for connectivity of these nodes through the internet. As IoT deals with heterogeneous nodes connectivity through the internet, it has evolved and the behavior of the potential user and several aspects of everyday life. The integration of IoT with CR can be used in communications, sensor networks for eHealth, logistics and security, smart technologies and many more [26]. This integration develops the effective communication system among the SUs [27]. One of the major parts in IoT nodes is of wireless sensor nodes. As these nodes are operated in free ISM bands [2] and face a lot of interference from numerous neighboring nodes. This interference is increasing as the number of nodes are increasing in the environment and efficiency of network decreases. Therefore, wireless sensor networks require a phenomenon to achieve efficiency to interconnect with the physical world in a more intelligent way. This gap can be covered by making the intelligent decisions based on the surrounding environment using cognitive radio technology [28].

2. ENERGY INGESTION OF WSNs

IoT and WSN have gained a lot of global attention in research and development. Therefore, it has initiated a massive development and implementation of sensors across diversified devices making them smart enough to communicate [29]. Nevertheless, wireless sensor nodes have some constraints regarding severe energy ingesting of the batteries, which is a substantial issue to its own existence causing scrambled network self-sufficiency. Consequently, reducing the energy consumption rate of batteries is an ultimate necessity for the existence and lifetime of sensor nodes in IoT. An ultimate challenge in IoT is how to communicate effectively while preserving and optimizing the energy levels of nodes. Subsequently, this communication is the most energy consuming part in these nodes. Figure 2 shows a descriptive energy consumption metric of a typical IoT sensor node [30].

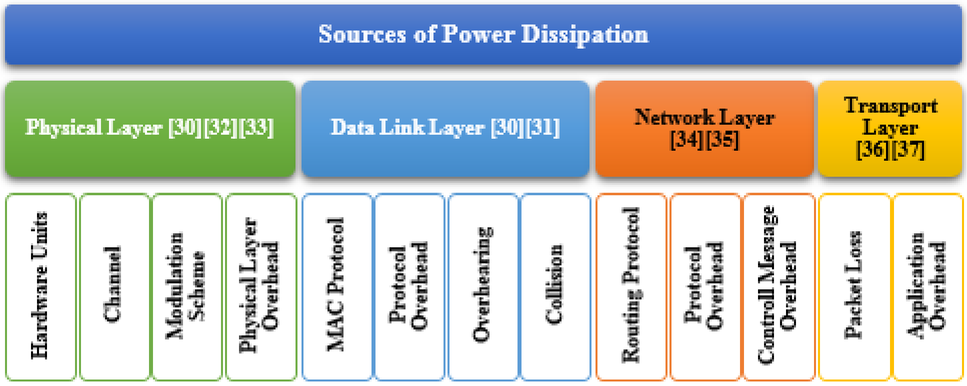

Figure. 2 Energy consumption metrics of a typical wireless IoT sensor node

In [31], an adaptive scheme is proposed to have power savings. This scheme works on the principal of redistribution and association for the green wireless networking and the base some modifications (station distribution and aggregation functions) are made in IEEE 802.11a and evaluated the performance of the scheme under different scenarios. Results show a considerable amount of energy that can be saved using this scheme. In [32], a power consumption investigation is done on the physical layer and considering the security aspect. Specifically pointing the security issues under the presence of eavesdropper along with physical circuitry requirements of sensor nodes for filtering and amplification of signals and the power consumption during emitting radio signals. A framework “relay-selection based cooperative beamforming” is proposed. Exponential complexity exhaustive search and linear-complexity relay ordering strategies are implemented to save energy while maintaining the security against eavesdroppers. The results show that the beamforming framework significantly outperforms the secrecy capacity with reduced computational complexity. In [33], a transmit beamforming scheme for base stations is proposed while considering the self-interference mitigation and physical-layer security. Zero forcing beamforming-based suboptimal algorithms are proposed to reduce the computational complexity. Golden search and closed-form solutions are used to obtain the results. The simulation results show considerable improvements in saving the energy while using the proposed algorithms.

In [34], a device-to-device communication survey is compiled focusing on network layer functionalities including addressing, routing, mobility, security and resource optimization. Limitations in currently available TCP/IP protocol and 6LoWPAN are addressed that how it can be implemented in IoT based environment. An interoperable device-centric protocol is proposed which theoretically shows that can be used with IoT environment better than the currently available solutions. In [35], a solid argument is aroused regarding IPv6 protocol that it can be used with WSNs but does not take power consumption into consideration. 6LoWPAN header compression algorithm applied to IEEE 802.15.6 in a solution to previously used IPv6. The simulation results are in a positive way that the improvement made is working to save the sensor node energy. In [36], a comprehensive survey is provided on current energy efficient technologies which can lead the IoT industry to the new horizons. Energy consumption units of a sensor node both in hardware and software level are classified and different approaches previously and currently used are discussed. In [37], a taxonomy of energy efficient attitudes in WSNs is projected. It presents a detailed study, discussions, and requirements to build an energy efficient mechanism for WSNs.

Several IoT energy optimization techniques have been proposed earlier, which were generally based on data transmission using single-radio. But now the research is focusing on multiple heterogeneous radio interfaces for short and long distance IoT nodes and gateways [38, 39]. Software Defined Radios (SDR) provides a conceivable approach to have capabilities of multi-radios. SDRs equipped with cognition generates CRs, these CRs can be replaced by the existing radios to have the capabilities of multi-radios by having a plus point of cognition [40, 41].

2.1 Layer based energy efficiency techniques

According to the energy consumption matric, several energy efficiency techniques are used to limit the energy consumption patterns of an IoT sensor node. Figure 3 represents a comprehensive layer based classification of energy efficiency techniques.

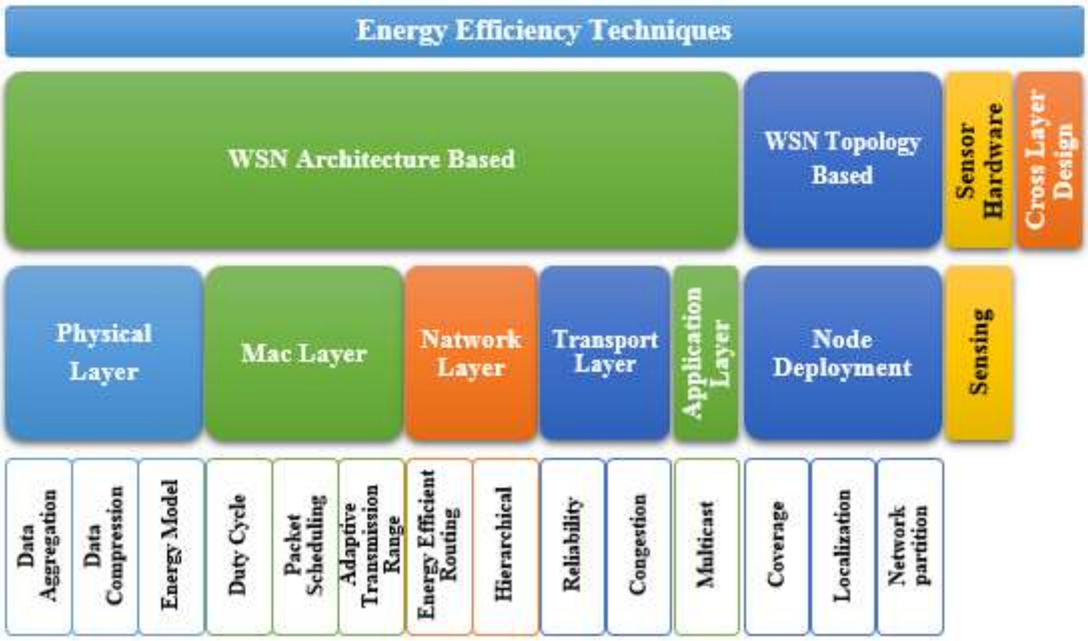

Figure. 3 Classification of energy efficiency techniques

2.1.1 Physical layer

Sensor nodes have a nature to perform modulation, transmission, reception, digitization, amplification and filtering any information to be received or to be transmitted. All these kinds of operations are done at physical layer circuitry and a considerable level of energy is consumed to perform these types of operations [42, 43]. In [44], a method of energy optimization is proposed for multi-hop wireless sensors networks. Used a matric for energy per bit and channel model and modulation scheme selection. Moreover, in [45], authors proposed a specified design for the upper layer to be aware of physical layer status. A scheme of protocols and application is designed that minimize energy consumption of the nodes.

2.1.2 Mac layer

Responsibilities of a MAC layer includes reliability, low access delays, high throughput, and energy efficiency. Collisions, interference, control packet overhead and overhearing at MAC layer a large amount of energy is required to do these types of operations and sometimes a huge amount of energy is wasted in these MAC protocol operations. Techniques like adaptive transmission range and period, packet scheduling, and duty cycling are majorly used in sensor networks to save energy at MAC layer [46-48].

2.1.3 Network layer

The network layer is responsible for routing process of a node to find out paths between the sources to destinations. It is an essential and key process to any network-based node. Finding out an optimal path between two communicating nodes is a key performance element for a sensor node regarding energy conservation. Because it needs repetitive transmission of control-packets between every hop from source to destination. This communication consumes a lot of energy as compared to the idle state of a node. Efficient routing techniques includes multipath routing, geographical routing, flat routing, and hierarchical routing [49, 50].

2.1.4 Transport layer

Duties of a transport layer in any network enabled device includes the creation of end to end connection between two host nodes, error recovery, flow control, and congestion avoidance. Connection and flow control is easy to handle as compared to error and congestion control. Hidden and exposed node problems are common in any wireless network. If it occurs, congestion also takes place so the data loss also occurs so an extra amount of energy is required to handle these issues [50, 51].

To save energy, energy-aware congestion avoidance, and energy efficient reliable communication mechanisms can be used as presented in [52], a congestion control mechanism, which considers node level congestion (NLC), and link level congestion (LLC) and results in the energy efficiency of the network.

2.1.5 Application layer

Application layer runs multiple application-level services. Energy can be saved through these application services by controlling those particular services which are energy hungry. This can be obtained by summation of control information in a distributed manner used for request and response. This will ultimately reduce the number of packets to transmit so the energy would be saved. In [51], a distributed framework is suggested that employs power conservation. The goal of the framework is to reduce the data collection and delivery costs.

2.2 WSN topology-based techniques

WSN node deployment also employs a key role on energy consumed by a node. The optimality in energy consumption mechanisms is achieved through active node positioning, coverage mechanisms, node localization and network partitioning techniques.

2.2.1 Node positioning scheme

The optimal node placement in a network provides such placement mechanisms through which optimality in energy consumption is achieved. These mechanisms estimate the optimal node placements, coverage and connectivity costs along with energy consumption comparisons. An optimal node placement is essential to achieve load balance and extended network operational lifetime [53]. In [54], a distributed deployment scheme (DDS) for homogeneous distribution of Mobile sensor Nodes within the candidate region is proposed. This scheme provides a minimum overlapping with maximum coverage. The DDS also provides a multi-path connectivity with the same characteristics. But this scheme is limited to a minimum mobility and does not employ scalability. This is also not suitable for real-time systems scenarios.

2.2.2 Coverage approaches

The QoS and performance of WSNs take a significant importance of coverage issues. It can be viewed as a target area, covered area, and a barrier coverage [55, 56]. The foremost objectives of area coverage technique are to cover a specified constituency and monitoring of each node in that region. Targeted coverage or point coverage is a mechanism used to cover a pre-specified fixed known location that needs to be observed. This scheme is used on a limited number of fixed immobile sensor nodes. The node placement is kept denser for better results. Because it is a fixed scheme so it provides guaranteed efficient coverage and monitoring. Barrier coverage in WSNs is used to make a barrier of sensor nodes. It is used specifically to sense movements across the sensor barrier. These coverage schemes are playing a vital role to minimize power utilization in sensor nodes and their lifetime [57].

2.2.3 Localization

Localization is a technique to identify pinpoint the location of sensor nodes. This technique is operated under local wireless based location identification instead of the global positioning system. The location identification scheme is further divided into target localization and self-node localization. The location is estimated on received signal strength, size of data and time taken to transmit and the angle on which it is received [58, 59].

In [60], a mechanism is proposed to acquire the location while reducing the energy consumption in localization. The nodes are activated in a probabilistic opportunistic way. This opportunistic probability is calculated using trilateration localization algorithm. In this way, number of nodes in a specific time slot are minimized so the active number of nodes would be less so the sensing range and area is reduced so a reasonable amount of energy is saved.

2.2.4 Energy efficient security

WSNs are the manufactured on the concept specified application domain. Due to this constraint, these sensor nodes are designed with limited resources. It usually has some processing power, memory, and communication range; all these operations need some power to operate. Concerning the security, there are no centralized mechanisms for monitoring the communication so all the security-concerned mechanisms are done by the node itself. This is also an extra overhead to the limited resourced node. Taking the security concerns and making it more secured needs high computational tasks so it consumes a significant amount of energy to perform these tasks. These are prone to network attacks like spoofed routing and acknowledgment information, Sybil attacks, sinkholes and wormholes attacks, selective packet forwarding and hello flood attacks [61-63]. Designing a secure mechanism which is resource efficient specifically regarding energy consumption against these routing attacks for WSNs is need to be addressed by the researchers.

3. FUTURE DIRECTIONS

Current IoT networks demand innovative means of lowering the energy consumption. Based on study provided in the previous sections various research gaps have been identified regarding needs of energy optimization. The future directions to minimize energy consumption in IoT wireless sensor nodes while maintaining its heterogeneity nature following schemes can be helpful to reduce the energy ingestion.

- Integration of cognitive radios with IoT sensors: a network-switching scheme for IoT sensors using cognitive radios based on energy consumption.
- Mobility profile based adaptive energy optimization schemes for fixed and mobile IoT sensor nodes.
- Adaptive energy profile creation and selection scheme based on current and previous energy consumption patterns and pushback communication scheduling policies.
- Adaptive selection scheme of control frame size and number of frames, based on sensor's energy consumption rate and remaining energy.

3.1. Methodology

To achieve the above-mentioned objectives of the scheme the following methodology regarding each objective is to be considered:

3.1.1 Integration of CR with IoT

In this setup, an IoT sensor node would not be a simple node; it would be equipped with CR capabilities. An adaptive scheme would be developed to implement this objective. IoT sensor nodes will communicate with its central access point in normal conditions, whenever a sensor node faces high transmission cost regarding energy consumption it would try to shift itself on CR mode and would transfer its data through PU's network. The cost analysis would be done on interference and retransmission ratio analysis afterward another analysis would be done between current transmission parameters cost and CR mode switching cost, whatever would be the beneficial one, sensor node would adapt that mode. Another analysis would be done regarding the distance between the sensor node and its access point. If the access point is far distant as compared to PU's then calculating transmission cost for a long distant AP and a short distant AP including CR mode switching cost would be done and node would adapt optimal transmission mode.

3.1.2 Mobility aspect

Sensor nodes are not always stationary nodes; it can be mobile nodes. Therefore, concerning mobile sensor nodes, same scheme would be implemented as of stationary nodes but the distance parameter would always be the changing one. So, to handle mobility, node's mobility patterns and previous decision regarding mode switch would be observed and mode switching would be done adaptively after analyzing the costs.

3.1.3 Adaptive energy profiling and pushback policy

An energy profiling concept would be used in which sensor node would take record of its energy usage in the past and would predict its own life at remaining energy. It can be done on hourly or day basis. The node would compare energy consumption rate between current day and time with previous day and time plus today's energy usage behavior analysis and would make decisions based on results weather to switch its mode or not. A predictive scheduling can also be done on these parameters and a node itself can make its own adaptive energy scheduling profiles. If a node is not capable enough to do these tasks, access points can also take part into this and make energy profiles of the sensor node and after analysis can make a schedule for sleep, awake and mode switching. After making the schedule this can be pushed back to the nodes to follow on.

3.1.4 Adaptive control frames algorithm

An algorithm would be generated for control frames (RTS, CTS, ACK). This algorithm would have the capability to switch between size and number of frames sent during communication. These sizes and number of frames would be predefined and the selection would be based on the rate of energy consumption and remaining energy level. Reducing the size and number of frames would provide a measurable energy saving.

4. CONCLUSIONS

A progress in evolving energy techniques that target to reform the skeleton of IoT is focused in this paper. We focused on the need for energy optimization for sensor nodes by considering the heterogeneous nature of IoT under the relationship of IoT and the cognitive radio networks in mobility aspects. Various research gaps have identified regarding needs of energy optimization. In the future prospects, directions to minimize energy consumption in IoT enabled nodes while maintaining its heterogeneous subsequent schemes can be helpful to reduce the energy ingestion. Integration of cognitive radios with IoT sensors can help to reduce the energy consumption rate. Another method to optimize the energy consumption is the mobility based adaptive energy optimization scheme that can also implement to reduce the transmission costs. Adaptive energy profiling with pushback communication scheduling policies is an alternative scheme to optimize energy consumption of the nodes. In addition, to reduce the energy ingestion is to develop an adaptive scheme for the selection of control frame size, selected on the status of energy level and needs. All the mentioned schemes can make a major contribution towards energy efficient IoT nodes. However, an advanced innovative energy optimized IoT node still needs to address by the researcher.

REFERENCES

1. Xia F, Y.L., Wang L, Vinel A, *Internet of things.* International Journal of Communication Systems, 2012. **25**(9): p. 1101.
2. Qureshi FF, I.R., Asghar MN, *Energy Efficient Wireless Communication Technique Based on Cognitive Radio for Internet of Things.* Journal of Network and Computer Applications, 2017.
3. Steenkiste Peter, S.D., Minden Gary, and Raychaudhuri Dipankar, *Future Directions in Cognitive Radio Network Research.* NSF Workshop Report, 2009. **4**(1): p. 1-2.
4. Wang, B., and K. J. Liu, *Advances in cognitive radio networks: A survey." Selected Topics in Signal Processing.* IEEE Journal, 2011. **5**(1): p. 5-23.
5. Wang, J., and Yuqing Huang, *A cross-layer design of channel assignment and routing in Cognitive Radio Networks.* IEEE, In Computer Science and Information Technology (ICCSIT), 2010. **7**: p. 542-547.
6. Reardon, M., in *CNET*. 2008.
7. FCC, in *Federal Communications Commission*. 2017.
8. Akyildiz, I.F., Won-Yeol Lee, Mehmet C. Vuran, and Shantidev Mohanty, *NeXt generation/dynamic spectrum access/cognitive radio wireless networks: A survey.* Computer networks, 2006. **50**(13): p. 2127-2159.
9. Liu, Q.Z.H.a.K.J.R., *Resource Allocation for Wireless Networks: Basics, Techniques, and Applications.* Cambridge Univ. Press, 2008.
10. Ghasemi, A., and Elvino S. Sousa., *Fundamental limits of spectrum-sharing in fading environments.* IEEE Transactions on Wireless Communications, 2007. **6**(2).
11. Kang, X., Ying-Chang Liang, Hari Krishna Garg, and Lan Zhang, *"Sensing-based spectrum sharing in cognitive radio.* IEEE Transactions on Vehicular Technology, 2009. **58**(8): p. 4649-4654.
12. Bhargavi, D. and C.R. Murthy, *Performance comparison of energy, matched-filter and cyclostationarity-based spectrum sensing.* Eleventh International Workshop of Signal Processing Advances in Wireless Communications (SPAWC) IEEE, 2010: p. 1-5.

13. Zhang, W., Ranjan K. Mallik, and Khaled Letaief, *Optimization of cooperative spectrum sensing with energy detection in cognitive radio networks.* Wireless Communications, IEEE Transactions on 8, 2009. **12**: p. 5761-5766.
14. Cabric, D., Shridhar Mubaraq Mishra, and Robert W. Brodersen, *Implementation issues in spectrum sensing for cognitive radios.* IEEE, In Signals, systems and computers, 2004. **1**: p. 772-776.
15. Sutton, P.D., Keith E. Nolan, and Linda E. Doyle, *Cyclostationary signatures in practical cognitive radio applications.* Selected Areas in Communications, IEEE Journal, 2008. **1**(26): p. 13-24.
16. Akyildiz, I.F., B.F. Lo, and R. Balakrishnan, *Cooperative spectrum sensing in cognitive radio networks: A survey.* Physical Communication Science Direct ELSEVIER, March 2011. **4**(1): p. 40–62.
17. Sun, C., W. Zhang, and K.B. Letaief, *Cluster-Based Cooperative Spectrum Sensing in Cognitive Radio Systems.* Communications, 2007. ICC'07. IEEE International Conference, 2007: p. 2511-2515.
18. Awin, F., Esam Abdel-Raheem, and Majid Ahmadi, *Agile hierarchical cluster structure-based cooperative spectrum sensing in cognitive radio networks.* IEEE, In Microelectronics (ICM), International Conference, 2014: p. 48-51.
19. Astaneh SA, G.S., *Relay assisted spectrum sensing in cognitive radio.* InSystems, Signal Processing and their Applications (WOSSPA), 2011. **7th International Workshop**: p. 163-166.
20. De P, L.Y., *Blind spectrum sensing algorithms for cognitive radio networks.* IEEE transactions on vehicular technology, 2008. **57**(5): p. 2834-2842.
21. Zeng Y, L.Y., *Eigenvalue-based spectrum sensing algorithms for cognitive radio.* IEEE transactions on communications, 2009. **57**(6).
22. Yucek T, A.H., *A survey of spectrum sensing algorithms for cognitive radio applications.* IEEE communications surveys & tutorials, 2009. **11**(1): p. 116-130.
23. Akyildiz, I.F., Lee, W. Y., Vuran, M. C., & Mohanty, S, *A survey on spectrum management in cognitive radio networks.* Communications Magazine, IEEE, 2008. **46**(4): p. 40-48.
24. Panwar, N., Sharma, S., Singh, A.K., *A survey on 5g: the next generation of mobile communication.* Physical Communication, 2016. **18**: p. 64-84.
25. Mavromoustakis, C.X., Bourdena, A., Mastorakis, G., Pallis, E., Kormentzas, G, *Anenergy-aware scheme for efficient spectrum utilization in a 5g mobile cognitive radio network architecture.* Telecommunication Systems, 2015. **59**(1): p. 63-75.
26. Khan AA, R.M., Rachedi A, *When Cognitive Radio meets the Internet of Things?* InWireless Communications and Mobile Computing Conference (IWCMC), 2016. **5**: p. 469-474.
27. Zhang, Y., Zheng, J., Chen, H.-H, *Cognitive Radio Networks: Architectures, Protocols, and Standards.* CRC Press, 2016.
28. Beltran F, R.S., Gutiérrez JA, *Understanding the current operation and future roles of wireless networks: Co-existence, competition and co-operation in the unlicensed spectrum bands.* IEEE Journal on Selected Areas in Communications, 2016. **34**(11): p. 2829-2837.
29. Misra, S., Misra, S. C., & Woungang, I, *Guide to wireless sensor networks.* Dordrecht: Springer, 2009.
30. Sinaie M, Z.A., Jorswieck EA, Azmi P, *A Novel Power Consumption Model for Effective Energy Efficiency in Wireless Networks.* IEEE Wireless Communications Letters, 2016. **5**(2): p. 152-155.
31. Lall, S., Nitin, N., Jaiswal, A.K. and Paulus, R, *Multi-Scenario Adaptive Station Re-Distribution/Re-Association Scheme for Green Wireless Networking.* 2016.
32. Qian, M., Liu, C. and Zou, Y, *Cooperative Beamforming for Physical-Layer Security in Power-Constrained Wireless Sensor Networks with Partial Relay Selection.* International Journal of Distributed Sensor Networks, 2016. **12**(3): p. 9740740.
33. Zhu, F., Gao, F., Zhang, T., Sun, K. and Yao, M, *Physical-layer security for full duplex communications with self-interference mitigation.* IEEE Transactions on Wireless Communications, 2016. **15**(1): p. 329-340.
34. Bello, O., Zeadally, S. and Badra, M, *Network layer inter-operation of Device-to-Device communication technologies in Internet of Things (IoT).* Ad Hoc Networks, 2016.
35. Wang, L., Hao, S., Yu, P. and Huang, Z, *Low-power Wireless Sensor Network protocol of Mobile Health based on IPv6.* Control Conference (CCC), IEEE, 2016. **35th Chinese**: p. 8479-8484.
36. Airehrour, D., Gutiérrez, J. and Ray, S.K, *Greening and Optimizing Energy Consumption of Sensor Nodes in the Internet of Things through Energy Harvesting Challenges and Approaches.* AIS Electronic Library, 2016.
37. Guru, R., *Energy Efficiency Mechanisms in Wireless Sensor Networks: A Survey.* International Journal of Computer Applications, 2016. **139**(14).
38. Foundation, O.C., in *Open Interconnect Consortium*. 2017.
39. Foundation, L., in *allseenalliance*. 2017.

40. Aust S, P.R., Niemegeers IG, *Advances in wireless M2M and IoT: Rapid SDR-prototyping of IEEE 802.11 ah.* Inthe Proceedings of the 39th IEEE Conference on Local Computer Networks (LCN), Demo Abstract, 2014: p. 1-3.
41. Tragos. E, A.V., & Papadakis. S, *Fighting Networking Heterogeneity in the Internet of Things.* ERCIM News, 2015. **101**: p. 33-34.
42. Gehrke, Y.Y.a.J., *The cougar approach to in-network query processing in sensor networks.* Special Interest Group on Management Of Data (SIGMOD), 2002. **31**(3).
43. Sandra Sendra, J.L., Miguel García and José F, *Toledo Power saving and energy optimization techniques for Wireless Sensor Networks.* JOURNAL OF COMMUNICATIONS, 2011. **6**(6).
44. Wang, M.H.a.T., *Optimizing Physical-Layer Parameters for Wireless Sensor Networks.* ACM Transactions on Sensor Networks, 2011. **7**(4).
45. Eugene Shih, S.-H.C., Nathan Ickes, Rex Min, *Physical Layer Driven Protocol and Algorithm Design for EnergyEfficient Wireless Sensor Networks.* ACM SIGMOBILE, 2001: p. 272-286.
46. Yang Liu, I., hairong Qi, *An energy efficient QOS-aware media access control protocol for wireless sensor networks.* in Proceedings of the IEEE International Conference on Mobile Ad hoc and Sensor Systems, 2005.
47. Hu W, C.Q., Corke P, O'Rourke D., *An Energy-efficient Rate Adaptive Media Access Protocol (RA-MAC) for Long-lived Sensor Networks.* . Sensors (Basel, Switzerland), 2010. **10**(6): p. 5548-5568.
48. Tz-Heng Hsu, T.-H.K., Chao-Chun Chen, and Jyun-Sian Wu, *A Dynamic Traffic-Aware Duty Cycle Adjustment MAC Protocol for Energy Conserving in Wireless Sensor Networks.* International Journal of Distributed Sensor Networks, 2012: p. Article ID 790131, 10 pages.
49. V. Raghunathan, C.S., Park.S, and M.B. Srivastava, *Energy-aware wireless microsensor networks.* IEEE Signal Processing Magazine, 2002. **19**(2): p. 40-50.
50. Christophe J. Merlin, W.B.H., *Schedule Adaptation of Low-Power-Listening Protocols for Wireless Sensor Networks.* IEEE Transactions on Mobile Computing, 2010. **9**(5): p. 672-685.
51. Chen, S.S.W.a.Z.P., *LCM: a link-aware clustering mechanism for energy-efficient routing in wireless sensor networks.* IEEE Sensor Journal, 2012. **13**(2).
52. W. Heinzelman, A.C.a.H.B., *Energy- efficient communication protocol for wireless microsensor networks.* in Proc. of the 33rd Annual Hawaii Int' Conf. on System Sciences, Maui: IEEE Computer Society, 2000: p. 3005-3014.
53. Zafar, S., *A Survey of Transport Layer Protocols for Wireless Sensor Networks.* International Journal of Computer Applications, 2011. **33**(1).
54. Ayadi, A., *Energy-Efficient and Reliable Transport Protocols for Wireless Sensor Networks: State-of-Art.* Wireless Sensor Network, 2011. **3**: p. 106-113.
55. Wen-Hwa Liao, S.-C.K., Mon-Shin Lin, *An Energy-Efficient Sensor Deployment Scheme for Wireless Sensor Networks Using Ant Colony Optimization Algorithm.* Wireless Personal Communications,, 2015. **82**(4): p. 2135-2153.
56. S. Bhattacharya, H.K., S. Prabh, & T. Abdelzaher, *Energy-conserving data placement and asynchronous multicast in wireless sensor networks.* In Proceedings of the 1st international conference on Mobile systems, applications and services, ACM, 2003: p. 173-185.
57. K. Kar, S.B., *Node placement for connected coverage in sensor networks.* In: Proceedings of the Workshop on Modeling and Optimization in Mobile, Ad Hoc and Wireless Networks (WiOpt'03), Sophia Antipolis, France, 2003.
58. Chhetri, M.B.a.S., *A Survey on the Coverage of WSNs.* International Journal of Advanced Research in Computer Science and Software Engineering, 2013. **3**(3).
59. Y. Weng, W.X., and L. Xie, *Total least squares method for robust source localization in sensor networks using TDOA measurements.* International Journal of Distributed Sensor Networks, 2011. **8**.
60. Xie, X.Q.a.L., *Source localization by TDOA with random sensor position errors—part I: static sensors.* in Proceedings of the 15th International Conference on Information Fusion, 2012: p. 48–53.
61. Ho, K.C., *Bias reduction for an explicit solution of source localization using TDOA.* IEEE Transactions on Signal Processing, 2012. **60**(5): p. 2101–2114.
62. Long Cheng, C.W., Yunzhou Zhang, Hao Wu, Mengxin Li and Carsten Maple, *Review Article A Survey of Localization in Wireless Sensor Network.* International Journal of Distributed Sensor Networks, Hindawi Publishing Corporation, 2012. **12**.
63. Abduvaliyev, A., Al-Sakib Khan Pathan, Jianying Zhou, Rodrigo Roman, and Wai-Choong Wong, *On the vital areas of intrusion detection systems in wireless sensor networks.* IEEE Communications Surveys & Tutorials 2013. **15**(3): p. 1223-1237.

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