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Cognitive-Radio-Based Internet of Things: Applications, Challenges, and Future Research Aspects

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Abstract*—*Trend technology and recent research are moving toward cognitive radio and Internet of Things, is believe that the IoT Objects are meaningless without cognitive radio capabilities a new research dimension has arose due to equipping IoT with CRNs named CR-based IoT. In this research a survey is presented on CR-based IoT systems. Potential applications of CR-based IoT System are introduced. In the end the research challenges, issues and the future direction for these CR-based IoT networks are introduced)

Keywords— Cognitive Radio (CR), Internet of Things (IoT) ; CR-based IoT.

Introduction The present-day developments in ICT have presented new paradigms like Internet of Things (IoT) and Cognitive Radio. With the recent developments in machine-to-machine (M2M) communications, IoT networks are changing the daily life of people through mobile connectivity that gives rise to the "Internet of Mobile Things (IoMT)" paradigm. IoT is the interconnection of different objects through the Internet using different communication technologies. The objects are equipped with sensors and communication modules. These objects have some characteristics: mobile or static, with or without energy constraint, able or not able to interact with the physical world, and so on. In the literature, IoT has been defined by many researchers in different manners [1, 2], The IOT concept was coined by a member of the Radio Frequency Identification (RFID) development community in 1999, and it has recently become more relevant to the practical world largely because of the growth of mobile devices, embedded and ubiquitous communication, cloud computing and data analytics.[3]. IOT defined into three categories as below: Internet of things is an internet of three things: (1). People to people, (2) People to machine /things, (3) Things /machine to things /machine, Interacting through internet.

Internet of Things Vision: Internet of Things (IoT) is a concept and a paradigm that considers pervasive presence in the environment of a variety of things/objects that through wireless and wired connections and unique addressing schemes are able to interact with each other and cooperate with other things/objects to create new applications/services and reach common goals. In this context the research and development challenges to create a smart world are enormous. A world where the real, digital and the virtual are converging to create smart environments that make energy, transport, cities and many other areas more intelligent. [4, 5]. For different IoT services, the quality of service (QoS) is evaluated by parameters, such as latency, reliability, power consumption as well as throughput. In addition, its computing capabilities, memory, and energy efficiency determine the performance of the connected devices. The deployment of cognitive radio network (CRN) techniques for future wireless networks could be helpful in realizing the envisioned tactile Internet [sustainable information centric network and intelligent next generation networks [6]. A numerous communication technologies are proposed for IoT from wire to wireless solutions, but wireless techniques are gaining popularity due to their flexibility. However, range, data bandwidth support, and availability of spectrum are major concerns. In addition, IoT applications are expected to introduce massive data into the network, and there is a strong desire to tackle this challenge. Recent trends of research in cognitive radio networks (CRNs) have drawn attention as a potential solution [7]. Using CR to enable IoT objects, can effectively utilize the unused spectrum who already owned by primary user (PU). CR is an intelligent wireless communication technique, which realizes his surroundings in all cases. As we introduced the paper here and

the rest of the paper is categorized as follows; Section II mentions the applications of CR based IoT. Section III presents a related work of CR and some of detection, challenges facing CR- Based IoT network, the future aspects of CR- Based IoT

THE APPLICATIONS OF CR-BASED IOT

The IoT application area is very diverse and IoT applications serve different users. Different user categories have different driving needs. This section is presenting potential application of IoT that can benefit from CR networks.

Healthcare:

Advanced computational research like Internet-of-Things (IoT) and Artificial Intelligence (AI) is the current digital technologies that can be applied to tackle major clinical problems associated with crisis, applications of CR-Based IoT already in the practical domain. smart sensors are deployed to keep track of Patients Surveillance such as physical condition, temperature of the body, glucose degree, blood pressure and others. With far off tracking, medical personnel constantly observes the parameters. wi-fi answers are already there; however, it's miles urgent that smooth monitoring is ensured. For this, healthcare facts are to be relayed to Medical field staff of workers without any want for assigning spectrum. CR-based IoT frameworks can achieve this to long ranges without any worries about spectrum availability [7].

Residential and Home Appliances:

IoT contributes the internet connection and remote management of mobile appliances, incorporated with a variety of sensors. Sensors may be attached to home appliances, like air-conditioning, TV, lights and other environmental devices besides detection system which is attached to the entrances accesses like windows and doors. Home vitality administration is as of now display in the frame of certain illustrations such as keen fridge and keen lights, consecutively. ..etc. [8].

Smart Cities:

an urban development uses different types of electronic methods and sensors to collect data that encompasses integration of information and communication technology (ICT) systems and IoT. The inspiration driving smart city is the arrangement of electronic-services to users for improved way of life in an eco-accommodating way. To facilitate this continuous connectivity will be essential, so an information and communication system will be the backbone. Data gathering and user interaction will also be an important aspect. CRNs can support the continues connectivity issues [7]**. t**he new era of the Internet of Things is driving the evolution of conventional Vehicle Networks into the Internet of Vehicles (IoV). Being in generation of Internet connectivity, there is a need to stay in safe and hassle-free environment Recently, trends are shifting toward less dependence on human beings where vehicle control is achieved through the integration of communications, controls, and embedded systems**.** IoV mainly are Three Types and they are Vehicles-To-Vehicles, Vehicles-To-Infrastructure and Vehicles-To-Cloud IoV is expected to be an autonomous decision maker for traveling. Safe navigation may be possible in the future through information exchange from vehicles to vehicles, from sensors attached on vehicles, and through users' intentions. The challenge in IoVs is the availability of spectrum for mobile vehicles, and CRNs can be a good solution due to their long range and interference-free spectrum sensing [9].

Smar Grid:

The **Smart Grid** is part of an **IoT** framework, which can be used to remotely monitor and manage everything from lighting, traffic signs, traffic congestion, energy consumption monitoring and management Wind Turbines / Power house: Monitoring and analyzing the flow of energy from wind turbines & power house, and two-way communication with consumers' smart meters to analyze consumption patterns, Controller for AC-DC power supplies that determines required energy, and improve energy efficiency with less energy waste for power supplies related to computers, telecommunications, and consumer electronics applications, also Monitoring and optimization of Photovoltaic Installations performance in solar energy plants One major

drawback here is the exchange of huge volumes of data from several meters/devices in a limited spectrum transfer speed without obstructions to long distances [10].

Smart Environment:

Control toxic gases and CO2 emissions of factories and cars, Monitoring of combustion gases and preemptive fire conditions to define alert zones. Weather forecast conditions monitoring such as humidity, temperature, pressure, wind speed and rain, Earthquake Early Detection

Hardware design consideration

The efficient utilization of Cognitive Radios requires appropriate hardware design to carry the massive exchanged data besides comparing the CR antennas used in one frequency spectrum are not the same in size as the ones which used in some other spectrum (ISM 2.4 GHz). Moreover,

When taking into account multiple parameters simultaneously such as transmission power, delay,

and transmission rate, it becomes a very complex problem to solve. transmission power levels are varying with regard to the environment. Selection of single-radio or multi-radio is also required [11]. Connecting IoT objects to the networks requires gateways. High flexibility, security, scalability, and energy efficiency should be considered in Gateway's design. Additional requirements arise in the form of efficient spectrum resource utilization in the case of CR-based IoT objects, especially in a multi-user scenario. Spectrum access is performed individually for CR users, but if IoT objects are energy-constrained, gateways may perform spectrum sensing for them. Geo-location-based spectrum searching with history keeping may be a good option. Flexibility and interoperability may be achieved through SDRs [7]. The CR technology normally includes nodes-based architecture with proper control strategies is an efficient solution for heterogeneous networks. However, this yield to some security issues as uniform security standards is not applicable to all heterogeneous networks. This is a prime concern for CR based heterogeneous network [12]. Regularization and standardization have been a vital point of conflict that needs to be addressed on urgent basis. The legal aspects for the usage of the CRNs in licensed spectrum needs to be addressed by concerned agencies as no unlicensed wireless application would be allowed to access to the ownership spectrum without proper permissions. This may create inconvenience, threat to security & surveillance and also disrupt the services to the PUs [12]. The proper detection of presence of PUs is most crucial i.e., categorization between the Pus signal and the Sus signal is a challenging task. In addition, presence of multiple licensed users will have variety of signals in the same band which is one more key challenge [12].

Massive Data Management

As of today, all future technologies including CR – Based IoT are dealing with huge volume of data thus Managing the huge volume of data from CR-based IoT objects in the future will pose a big problem. The collected data is meaningless unless it is properly analyzed and interpreted. TheCR- Base IoT will be highly populated by large numbers of heterogeneous Objects and devices which will lead to high-dimensional and nonlinearly separable collected data, this collected data will be heterogeneous and difficult to process. This requires effective algorithm design with semantic capability that is capable enough to support linear/nonlinear and high-dimensional data processing [13]. Data management challenges for IoT has seen to be emerging rapidly and no doubt with the use of IoT in CRN more and more data is being created Therefore, advanced data mining techniques are needed to mine streaming data from sensor networks. The challenge lies in the shortage of skilled data analysts and the need for more research to develop and implement advanced mining tools to mine streaming data from CRN and sensor networks [14].

Spectrum challenges

the number of IoT objects networked is growing with regard to radio frequency resource, wireless transmission needs to be allocated efficiently to enhance radio spectrum utilization. In order to achieve this task spectrum sensing is required, Spectrum sensing is considered the main and fundamental step. The object of CR- Based

IoT have to look for unutilized frequency in a dynamic environment in the presence of a number of PUs, and the problem is raised when PUs are in the same band, while distinguish between the licensed and unlicensed frequency signal is recommended. Sensing technique considered consuming energy and time. Hence, fast and energy efficient algorithms should be designed. During sensing the spectrum CR doesn't perform any task, it is recommended to employ more than one radio, so one radio can perform sensing task and another radio transfers the data. If spectrum is sensed ideally, making a decision among searched bands about data transfer is an issue. Of multiple bands, there is a possibility that certain bands do not meet application-specific QoS requirements. Critical applications need real-time answers, while non-critical applications may compromise on response time. Moreover, assigning spectrum among multiple CRs is also a challenge, and requires resource-shared and application-specific algorithms [7].

Standardization Challenges

Standardization is considered as one of the critical factors of the IoT evolution. Without global standards, the complexity of IoT Objects that need to exchange data (with all related aspects such as, addressing, associated directory services, data repository ...etc.) will expand exponentially. Standardization efforts in IoT are still in their early stages, and standardization of CR-based IoT is a meager topic to discuss. developing semantic standards is one of the important problems as it can accelerate the process in the direction of interoperable solutions.

For successful semantically operable scenarios Frameworks of CR-based IoT have to support a large number of diversified devices. Therefore, the main standards which are of concern in CR-based IoT are: technology and regulatory standards. Technology standards include wireless communication, network protocols, data aggregation standards; and standards, include security and privacy of data, security solutions, cryptographic primitives. Finally, investigating IoT as a service could be the solution for future standardization [14].

Security and Privacy Challenges

As the IoT expands and becomes more interwoven into the fabric of recent promising technologies Same security levels cannot be applied at all situation due to the heterogeneity of CR-based IoT frameworks which leads to security problems. The adaptive capability of CR can become a security problem as an intruder may pretend to be a CR [11].

Conclusion:

The appealing capabilities of Internet of Things (IoT) and the idea of cognitive radio have raised the possibility of making a better world despite of their early stage and very little work has done in IoT field. Hence, CRN-Based IoT is still new technology to be applicable and need a little more work This article has given a sight and application of CRN- Based IoT. It is anticipated that IoT without cognition will just be useless with regard to the existing network infrastructure. utilization of the spectrum resources can be increased by IoT Objects in this underutilized spectrum. finally, we envision that the provided study is still considered as a small step towards brighter and fruitful research direction.

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