Cross Layered Approach for Quality of Service Communication In Cognitive Networks

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Abstract - Quality of service (QOS) *communication is a challenging task for WSN based smart grid application due to electromagnetic interference, equipment noise, multipath affects and obstruction in harsh smart grid environment. Sophisticated, reliable and fast communication infrastructure is necessary for connecting huge amount of distributed elements to ensure improved efficiency, reliability, flexibility for those included in smart grid like producers, operators, customers. To overcome this challenge cognitive communication based cross layer frame work has been proposed. Alongside ICT (Information and Communication Technology) act as a fundamental element in growth and performance of smart grids. This frame work utilizes cognitive radio technology to minimize noisy, cognate spectrum bands for reliable and high capacity links for wireless communication in smart grid. Also differentiates traffic flow based on priority classes according to their QOS needs to meet the QOS requirements of diverse smart grid application attributing delay, reliability of data for efficient support to QOS through the channel control, flow control, scheduling, routing decision, a DCA (Distributed Control Algorithm) is presented. This paper employs dynamic spectrum access to overcome channel impairments, defining multi attribute priority classes and designing DCA for data delivery for maximizing network utility over a QOS constraints results in achieving required QOS communication for smart grid.*

***Key Words*: Smart grid, QOS (Quality Of Service), Cognitive radio technology, Distributed Control Algorithm (DCA), Cross layer frame work, Cognate spectrum band.**

1.INTRODUCTION

To employ various monitoring and actuation devices to autonomously monitor, diagnose, control and efficiently operate the power equipments, smart grids are considered as next generation power system. They require complex two ways communication infrastructure, sustaining power flow between intelligence components, sophisticated computing, information technologies and business applications. They provide new approaches in grid management by applying demands and management, providing grid energy storage for load balancing to overcome energy fluctuations by using intrinsic nature of Renewable Energy Systems (RES). It prevents wide spreads power grid cascading failures, provides storage, matching the generation and balance the load.

To achieve seamless, reliable and low cost remote monitoring and controlling the smart grid wireless sensor networks (WSN's) are considered as a promising technology. The present and envisioned applications of WSN's in power grid will results in wide range, including advance metering, remote power system monitoring and control, electricity fraud detection, fault diagnostic, demand response, dynamic pricing, load control, energy management and power automation. But Quality Of Service (QOS) requirements and specifications for smart grid applications are different in terms of reliability and communication delay. It has been found from recent field test that, due to dynamic topology changes, obstructions, electromagnetic interference, equipment noise, multipath effects, fading. Wireless links in smart grid environment have higher packet error rates and variable link capacity. This will result in both time and location dependent delay and capacity variations of wireless links in smart grid environment. Support reliable and real time data delivery under adverse transmission condition are the key design challenges in smart grids.

At this end, for improved spectrum utilization in smart grid environment, Cognitive Radio Sensor Network (CRSN) has been proposed which can enhance overall network performance by dynamic spectrum access. Cognitive radio will utilizes the temporarily unused spectrum, which is called spectrum hole. At some particular spectrum band if a Secondary User (SU) gets high noise and/or Primary User (PU) signal, secondary user migrates to another spectrum hole or stays in the same band without interfering with the licensed user by adapting its communication parameters. There will be no legitimate primary users in unlicensed spectrum band and all the users have the same right to access the unlicensed spectrum but use of noisy channel can be prevented. Hence the unique challenges of smart grid application can be addressed using cognitive radio. The challenges are time and space varying spectrum characteristics, reliability, latency, harsh propagation conditions and energy constraints for low power sensor nodes.

2.RELATED WORK

In "QOS routing in smart grid" [1], proposed by Husheng Li and Weiyi Zhang, in smart grid QOS mechanism is proposed for the communication system due to the significant impact of degradation in delay. The derivation of QOS requirement is incorporated by smart grid. That applies QOS routing in the communication network. Dynamic of power load and load price mapping are studied for deriving the QOS requirement. Here delay is one of the QOS metrics, impact of this QOS metric along with the other QOS metrics are analysed. The revenue will be maximized through an optimization problem which is derived by the QOS. A simple greedy QOS algorithm is proposed based on the derived QOS requirements that results in the high speed routine in smart grid. In smart grid effective and secure communication in QOS is achieved using the greedy algorithm.

In "Probabilistic QOS guarantee in reliability and time line domain in WSN" [2], proposed by Emad feleban, Chang-Gun Lee, Eylem Ekici, Ryan Boder and Serdar Vural, A novel packet delivery mechanism called Multi-path and Multi-Speed routing protocol (MMSPEED) is proposed for probabilistic QOS guarantee in WSN. Timeliness and reliability are the two quality domain in which QOS provisioning is performed. In the timeliness domain multiple QOS levels are provided by guaranteeing multiple packet delivery speed options. In the reliability domain, probabilistic multipath forwarding provides various reliability requirements. Global network information will not be used for realizing QOS provisional, but by locally employing localized geographic packet forwarding can be made greater with dynamic compensation. This compensation compensates the local division inaccuracy when a packet is travel towards its destination. Scalability, adaptability and an end-to-end communication requirement will be achieved locally using MMSPEED. By this effective capacity of sensor networks will be improved significantly.

In "A cross layer design for QOS support in Cognitive Radio Sensor Network for smart grid application" [3], proposed by Ghalib A, Vehbi C, Gungor and Ozgur B,Akant. To meet the QOS requirements for smart grid a cross layer is proposed. For the control and monitoring operation of CRSN, these smart grids are employed. Routing protocols that are appropriate for the QOS support are not able to handle the traffic of different characteristics in smart grid simultaneously. Hence, a set of priority classes, exhibiting drivers QOS requirement are defined by considering the traffic heterogeneity of smart grid application. In order to distinguish the traffic for respective service, Weighted Network Utility Maximization (WNUM) is the problems formulated which has objective to maximize the weighted sum of flow service. By performing joint routing, dynamic utility optimization problem will be solved. This solution is referred to as cross layer heuristic solution.

In "QOS networking for smart grid distribution monitoring" [4] proposed by Wei Jun, Xia ojing Yuan, Jianping Wang, Dong Han and Chongwei Zhang. It is necessary to have a guarantee QOS for the realization of smart grid vision for the communication and networking technology in smart grid ranging from power generation, transmission, distribution, customer application. Zigbee (using IEEE 802.15.4) and Bluetooth (using IEEE 802.15.1) are the low cost wireless protocols which are especially useful for the power distribution system monitoring and customer application. But they have short propagation distance and support QOS. Here, QOS is being added into these low cost protocols that provides differentiated service for traffic of different priority. Here, the proposed QOS enhancement improves delay and throughput of the network that ensures the performance of smart grid distribution monitoring and control.

In "Communication requirements and challenges in the smart grid" [5], proposed by Faycal Bouhafs, Michael Mackay, and Madjid Merabti, proposes smart grid communication requirement and the important technical challenges are identified. They suggests to design a new communication architecture that will support smart grid services and control operations. They suggested that recent program done in communication technologies and protocols should be utilized by future communication architecture. This proposed communication architecture should be reliable, scalable, and extendable for the future smart grid services and applications.

In "opportunities and challenges of Wireless Sensor Networks in Smart Grids"[6], proposed by Vehbi C. Gungor, Bin Lu, and Gerhard P. Hancke, they overviews opportunities and challenges of Wireless Sensor Networks and also their application for electric power systems. They give an idea for the future work in an unexploited research area in diverse smart grid applications. Some different electric power system environments are 500kv substations, industrial power control room and an underground network transformer vault. Here statistical characterization of wireless channel in such environments is studied. In real world power delivery and distribution systems, field tests have been performed on IEEE 802.15.4 complaint wireless sensor nodes in order to measure background noise, channel characteristics, attenuation in 2.4GHz frequency band. This paper provides overall guide design decision and tradeoffs for WSN based smart grid applications

In "end to end communication architecture for smart grid"[7], proposed by Thilo Souter Senior member, IEEE and Maksim Labashov. In order to coordinate the generation, distribution and consumption of energy, smart grids are heavily dependent on communication. Also distributed power plants based on renewable energies are taken. The appropriate solution for this is a variety of communication partners, a heterogeneous network infrastructure consisting of internet protocols and suitable field network. In this paper two tier infrastructure and possible field level network with attention to metering, supervisory control and data acquisition application are investigates. To solve the problem of network integration, combination of gateway and tunneling solution is proposed which allows semitransparent end to end connection between application servers and field nodes. The easy of approach and implementation details are discussed using an example of power line communication and IP based protocols.

3. NETWORK MODEL

To achieve seamless, energy efficiency, reliable remote monitoring and control in smart grid applications, WSN is a sensational technology. Sensor nodes are operated through batteries which are having limited energy source.

These sensor nodes are employed with cognitive radio interface. The assumption is that the sensor nodes use only a single radio which will switches among different data channels and predefined control channels. This employed radio transmits a fixed transmission power level P_t. Let H_u(t) denotes a set of channels sensed. These sensed channels are free of PU transmission by a SU u at a time period t slotted over a time slots {0, 1, 2,...}. The corresponding interference power set of $I_u(t) = \{I_u^1,..., I_u^{|H_u|}\}$ and $B_u(t)= \{b_u^1,..., b_u^{|H_u|}\}$ is the time varying capacity achieved on each channels. This time varying capacity can be calculated using shannon capacity formula.

For the modeling of smart grid traffic, C be the set of priority classes and $\Omega=\{\omega_1,..., \omega_{|c|}\}$ be the set of weights assigned to priority class for prioritizing. β, τ and α are the QOS parameter of each priority classes. $\omega_c \in \Omega$ is a priority weight of class c ∈ C. This priority weight is bounded by high and low threshold values for the attributes such as $\{(\beta_{min}^c, \beta_{max}^c), (m_{min}^c, m_{max}^c), (\alpha_{min}^c, \alpha_{max}^c)\}$. The tolerance of the attribute is corresponds to the threshold interval of each attribute in a class. Similarly the arbitrary number of flows exists in each class. Such that F_c(t) defines set of flows in the class c at a time slot t and Ƒ defines the set of flows present in the entire network, which is given by $Ƒ= \square_{c\in C} F_c$. So, the ith flow of class c is entitled to utilize the respective service, where $\beta_{min}^c \le \beta_i \le \beta_{max}^c$, $m_{min}^c \le m_i \le m_{max}^c$ and $\alpha_{min}^c \le \alpha_i \le \alpha_{max}^c$.

Utility function is defined on achieving is desired QOS to express the utility of a particular application. Delay requirement utilization depends on the probability that the delay is achieved by the network, when the application specifies its delay requirement to get the benefits. For example communication delay of demand response management application will be set to balance the demand and supply. Otherwise it will effect in terms of excessive energy production or may leads to storage. For the reliability and bandwidth utility the similar perception is applied. Let $\square_u(\beta_i)$, $\square_u(m_i)$ and $\square_u(\alpha_i)$ represent the utility at meeting data rate, delay and reliability requirement of flow i passing through u at time t. The communication parameters of the utility function is calculated as,

$$\square_u^c(\beta_i, m_i, \alpha_i) = \omega_c^\beta \square_u(\beta_i) + \omega_c^m \square_u(m_i) + \omega_c^\alpha \square_u(\alpha_i)$$

Where, ω_c^β, ω_c^m, ω_c^α are the weighting coefficients which intensify each of the QOS parameters in a class separately and $\omega_c = \omega_c^\beta + \omega_c^m + \omega_c^\alpha$. In terms of profit or benefit, ω_c is translated to explicit application utility on achieving appropriate network service.

3.1. Distributed Control Algorithm

A DCA (Distributed Control Algorithm) is constructed from interconnected processes and is designed to run on computer hardware. Telecommunications, Scientific computing, Distributed information processing and real time process control are some varied applications. Areas of distributed computing of this algorithm, Leader election, Consenses, Distributed search, Spanning tree generation, mutual exclusion and resource allocation are some of the problems solved by DCA.

DCA is typically executed concurrently since it is a type of parallel algorithm, where a different parts of the algorithm runs simultaneously upon independent processors. Here the separate parts of the algorithm will have limited information of what other parts of the algorithms are doing. The coordination of the behaviour of individual parts of the algorithm in processor failure and unreliable communication links, are the major challenges in the development and implementation of this algorithm. It is required to choose the distributed control algorithm based on characteristic of the problem, characteristics of the system, type, probability of the processor, link failures, kind of interprocess communication, level of timing synchronization between different processes.

3.2.Tabular column

The parameters are defined over the level unimportant = 0, low = 1, high = 2 and critical = 3 in a proposed QOS class.

Class	B	T	α
Real time/ Reliable (XRtRe)	1	3	3
Real time/ Non-reliable (XRtX)	1	3	1
Non-real time/ Reliable (XXRe)	1	0	3
High-rate / Real time/ Non-reliable (HRaHRtX)	2	2	1
Critical-rate/ Non-real time/ Reliable (RaXRe)	3	0	3

The capacity of a channel h of bandwidth δ is limited due to the interference in the power system and is calculated as follows,

$$b_h^u(t) = \delta \log(1 + K.\gamma_{\vec{uv}} / I_h^v)$$

Where, K is the limiting factor due to the bit error rate and it can be obtained as K=$-1.5/\log(5 \times BER)$, this model is proved to be good for the modulation schemes like MQAM where constellation size is greater than or equal to 4. The signal strength $\gamma_{\vec{uv}}$ received at nodes transmitting at a fixed power P_t.

4.CONCLUSION

This paper employs cognitive radio communication in power system to circumvent the hostile propagation by presenting a cross layer framework and supports QOS for smart grid applications. The objective of this paper is to maximize the weighted service of traffic flows belonging to the different classes. It introduces a distributive control algorithm (DCA) solution which will completely improves the routing, medium access and physical layer functions. This paper shows that the performance of flows of higher priority classes will not be effected by the increase in the number of flows of lower priority class for their specified attributes. Under limited number of channels that are used by PU are assumed as an unwanted signal or noise. The performance and evaluation of each class with respect to attribute specification shows the increase in number of channels does not necessarily enhance the same ratio and it is limited.

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